CHAPTER 6

TECHNICIANS AND THE VEDIC PRIESTS

At the very outset of the present discussion, it may be useful to try to be clear about what we are going to argue. On circumstantial evidences—specially from the evidence of the *Sulva* geometry being indisputably the outcome of sophisticated brick technology, which was a prominent feature of the Harappan culture but which was totally absent in what is usually called the Vedic period—we are led to the view that this geometry was in all presumption developed in the Harappan culture. In the Harappan culture, however, the priests or priestly corporations were very likely to have a dual role. On the one hand, they were the 'organisers of production', while on the other, they were the 'administrators of superstition'—a point which we hope to discuss in some detail in our Chapter X. From this viewpoint, there is nothing *prima facie* impossible for them to have been the makers of the geometry under consideration, because as 'organisers of production' they were in need of having geometry as a conscious science. Therefore, our present argument is not that the *priest class as such* could under no circumstance be the makers of the geometry that comes down to us in the *Sulva* texts. What we are going to argue here is the *prima facie* difficulty of the *Vedic priests*, having been the makers of this geometry, whose social function and social position must have been basically different from those of the Harappan priests. From the Vedic literature itself, we have nowhere the impression that these priests were any longer the 'organisers of production'. Cut off from this social function, they became some kind of social parasites, subsisting mainly on the *daksina* or sacrificial gifts received from the patrons financing the sacrifices. In short, they were left only with the other priestly function, namely that of being the 'administrators of superstition'. What we are going to discuss in the present chapter is thus not the general question of the priest class having anything to do with the making of mathematics but specifically the possibility of the Vedic priests having the role.

1. PRELIMINARY REMARKS

Our discussion so far has hinged on one point. The mathematics in the Sulva texts was the outcome of the theoretical requirements of the technology of making and using burnt bricks, notwithstanding a body of magico-religious beliefs somehow sought to be associated with the brick-structures.

But this strongly goes against the usual assumption about the making of mathematics in ancient India, according to which it was created by the Vedic priests to meet the requirements of their sacrificial rituals.

It was A.C. Burnell (1840-1882), who, in his catalogue of the *Collection of Sanskrit Manuscripts* (1869), first drew our attention to Sulva texts for understanding "the earliest beginnings of geometry among the Brahmanas".[1] Since then the texts are extensively discussed by a number of outstanding modern scholars like A. Burk, G. Thibaut, B.B. Datta and many others, to whom we are basically indebted for explicating the mathematical contents of these texts. In our own discussion, we shall have to draw freely from their writings. In the present chapter, however, we shall try to explain why we feel obliged to differ from them on a point that appears to us to be historically very significant. All of them have on the whole assumed this mathematics was created by the Vedic priests. Let us first have some idea of this assumption and the *prima facie* grounds for it.

2. ORIGIN OF GEOMETRY : HERODOTUS AND RECENT VIEW

The usual assumption that Sulva mathematics arose to meet the requirements of the Vedic sacrifices leads Thibaut to the extent of arguing that here at last we have an unquestionable evidence for the genuinely Indian contribution to science. As he[2] puts it :

> We have been long acquainted with the progress which the Indians made in later times in arithmetic, algebra, and geometry ; but as the influence of Greek science is clearly traceable in the development of their astronomy, and as their treatises on algebra, etc. form but parts of astronomical text books, it is possible that the Indians may have

1. G. Thibaut in *SHSI* Vol. II, 417.
2. *Ibid.* 415-16.

received from the Greeks also communications regarding the methods of calculation. I merely say possible, because no direct evidence of such influence has been brought forward as yet and because the general impression we receive from a comparison of the methods employed by Greeks and Indians respectively seems rather to point to an entirely independent growth of this branch of Indian science. The whole question is still unsettled, and new researches are required before we can arrive at a final decision.

While therefore unable positively to assert that the treasure of mathematical knowledge contained in the *Lilavati*, the *Vijaganita*, and similar treatises, has been accumulated by the Indians without the aid of foreign nations, we must search whether there are not any traces left pointing to a purely Indian origin of these sciences.

Thibaut sees these in the *Sulva-sutra*-s the geometry embodied in which arose out of the requirements of the Vedic sacrifices. What, then, were the requirements of the Vedic sacrifices that is supposed to bring geometry into being? B.B. Datta explains, "According to the strict injunctions of the Hindu Sastra (or 'Holy Scriptures'), each sacrifice must be made in an altar of prescribed shape and size. It is stated that even a slight irregularity and variation in the form or size of the altar will nullify the object of the whole ritual and may even lead to an adverse effect. So the greatest care has to be taken to have the right shape and size of the altar".[3] Such a demand for precision could not be met without developing a sufficient amount of geometrical knowledge, and it is this that we find in the Sulva texts. Geometry thus came into being to meet the requirements of Vedic sacrifices.

This view of the origin of geometry seems to be endorsed by the immediate context as belonging to which the *Sulva* texts come down to us. It is the context of the sacrificial literature of the Vedic priests. We may thus have here a few words on this literature, specially those parts of it to which we shall have to refer repeatedly in the course of our own discussion.

The first fullfledged literature with the special theme of the sacrifices is called the *Yajurveda*. Tradition wants us to believe that there was once a very large number of schools of the Vedic priests, each with its own version (or recension) of the *Yajurveda*. A number of these actually survive for us,

3. B.B. Datta SS. 20.

of which we shall have to refer specially to the *Taittiriya Samhita* in which the question of Vedic fire altars is elaborately mentioned.

It is, of course, impossible to be exact about the date of this text, though on various considerations serious Vedic scholars think that the end of the period of the *Yajurveda* could not be later than 800 B.C.

Next in importance from the priestly point of view is a class of texts known as the *Brahmana*-s. These are fabulous in bulk, discussing all sorts of details of the sacrifices and often expressing sharp differences of opinion on ritual trivialities and "theological twaddles". Of these texts, the *Satapatha Brahmana* contains a long portion on the question of the fire altars and hence has special significance for purposes of our own discussion. It is impossible, again, to be exact about the date of the text, though the modern scholars are generally inclined to think that the end of the age of the *Brahmana*-s could not be later than 600 B.C.

Though exclusively concerned with the Vedic sacrifices, the *Brahmana* texts are really too vast, too complicated and often also too obscure and controversial to be of actual use for the practising priests. The need was thus felt for some kind of handbooks or manuals for their use. To meet this requirement, there grew in course of time another class of literature called the *Kalpa-sutra*-s. "They arose out of the need for compiling the rules for sacrificial ritual in a shorter, more manageable and connected form for the practical purposes of the priests. *Kalpa-sutra*-s dealing with the Srauta sacrifices taught in the *Brahmana*-s are called *Srauta-sutra*-s, and those dealing with domestic ceremonies and sacrifices of daily life, the Grhya-rites, are called *Grhya-sutra*-s".[4]

Directly attached to the *Srauta-sutra*-s are the *Sulva-sutra*-s: though separately classified under the *Kalpa-sutra*-s, the *Sulva-sutra*-s come down to us as forming parts of the *Srauta-sutra*-s. But there is another class of literature belonging to the *Kalpa-sutra*-s. These are called the *Dharma-sutra*-s and deal with religious as well as secular laws. Through these works, observes Winternitz, the Brahmins "succeeded in transforming the law of ancient India to their own advantage, and in making

4. Winternitz, I, 272.

their influence felt in all directions".[5] We shall later see the importance of these legal texts for understanding the general theoretical temper and sociological ideas of the Vedic priests, which, in their turn, are of immediate relevance for the generti problem of the formation of exact science in ancient India. For the present the point is that since the *Srauta-sutra*-s and the *Dharma-sutra*-s have the same origin, it will be a methodological error to try to understand the former without relating it to the latter. However, let us try first to be clear about the *Sulva-sutra*-s.

The Vedic priests belonged to various schools like those of Baudhayana, Apastamba, Katyayana, etc., each having *Kalpa-sutra* of its own. The *Sulva-sutra*-s, as appended to the *Kalpa-sutra*-s, also come down to us in somewhat different versions, —though on the whole the differences are minor. Of these, the *Sulva-sutra* of Baudhayana is viewed as the oldest and most important one for understanding the making of mathematics in ancient India. Next in importance is the *Sulva* text associated with the name of Apastamba. Five other *Sulva-sutra*-s are known to the modern scholars, as belonging to the schools of Katyayana, Manava, Maitrayana, Varaha and Vadhula. But these are of comparatively lesser significance.

It is impossible, of course, to be exact about the date of the *Sulva-sutra*-s. On various circumstantial evidences, however, it is believed that the dates of the Sulva texts associated with the names of Baudhayana and Apastamba are not likely to have been later than the third or second century B.C., though this could be somewhat earlier—but not earlier than the fifth century B.C. But these are to be understood as possible dates of the codification of the Sulva texts. The actual mathematical knowledge being codified in these could have come down from a distant past.

3. "WHAT IS TO BE DONE" & "HOW IS IT TO BE DONE"

Judging from the fact that the *Sulva-sutra*-s come down to us as forming parts of the priestly handbooks, nothing seems to be *prima facie* more natural than the usual assumption that the knowledge embodied in these developed in the priestly

5. *Ibid.* 275.

circles to meet certain requirements of the priest-craft. But the actual question of the making of mathematics in ancient India is much more complicated than can be answered merely by judging the context of the Sulva texts.

For this purpose, it is essential first of all to differentiate between two questions concerning the brick-structures, called the *citi*-s or *agni*-s. These questions are: First, "What is to be done?" Secondly, "How is this to be done?" We are going to see that the Vedic priests, *in the capacity of priests in the strict sense*, could be concerned only with the first of these two questions. However, the second question is clearly outside the scope of priestly specialization and could be faced only by technicians—the highly skilled brick-makers, masons, architects or engineers. Therefore, even admitting that a section of the Vedic priests could have somehow taken an absorbing interest in the second question, we have to admit further that these priests were taking the interest not in their priestly capacity but in the extra-priestly capacity of technicians and craftsmen.

However, it is difficult to imagine even this, because—as we shall later see—such a technological interest could be taken only by flouting not only the Dharmasastra norm but also a fundamental requirement of the priestly ideology favouring deliberate mystification, and hence rejecting the demand for precision without which the craftsmen and technicians could not operate.

To this needs to be added only one point. The mathematical content of the *Sulva* texts developed not from the attempt to answer the first question, viz. "What is to be done?", but from the attempt to answer the second one, viz., "How is it to be done?" Thus the possibility of the priests, in the restricted capacity of priests proper, creating this mathematics is a remote one. The presumption, on the contrary, is that those who created this mathematics did it in the capacity of the technicians, notwithstanding the fact that the mathematical knowledge—though developed to meet the theoretical requirements of the technologists—was somehow codified in texts that were appended to the priestly handbooks.

Let us see some of the main points for taking such a view.

"The Vedic sacrifices", observes Datta, "are mainly of two classes: *Nitya* (or 'indispensable', 'obligatory') and *Kamya*

('optional', 'intentional'). The performance of the sacrifices of the former class is obligatory upon every Vedic Hindu... But it is not so with the sacrifices of the second kind. For they are to be performed each with the sole motive of achieving a special object".[6]

It may be convenient for our discussion to begin with the second kind, the fire-altars recommended for which are quite elaborate and hence their physical construction required a good deal of technical skill.

The first question obviously is : Why did the Vedic priests recommend such elaborate fire-altars with definite shapes and sizes? The standard answer to this is to be found in the *Taittiriya Samhita* (v.4.11) which, though often quoted, may be quoted over again in rough English rendering :

He who desires cattle should pile a piling with the metres ; the metres are cattle ; verily he becomes rich in cattle. He should pile in hawk shape who desires the sky(heaven) ; the hawk is the best flier among birds; verily becoming a hawk he flies to the world of heaven. He should pile in heron form who desires, 'May I be possessed of a head in yonder world' ; verily he becomes possessed of a head in yonder world. He should pile in the form of an Alaja bird, with four furrows, who desires support ; there are four quarters ; verily he finds support in the quarters. He should pile in the form of a triangle, (*prauga*, literally the fore-part of a cart), who has foes ; verily he repels his foes. He should pile in triangle form on both sides, (*ubhayata-prauga* = rhombus), who desires, 'May I repel the foes I have and those I shall have' ; verily he repels the foes he has and those he will have. He should pile in the form of a chariot-wheel, who has foes ; the chariot is a thunderbolt ; verily he hurls the thunderbolt at his foes. He should pile in the form of a wooden trough who desires food ; in a wooden trough food is kept ; verily he wins food together with its place of birth. He should pile 'one that has to be collected together' (? *Paricayyacit*), who desires cattle ; verily he becomes rich in cattle. He should pile one in a circle, who desires a village ; verily he becomes possessed of a village. He should pile in the form of a cemetery, who desires, 'May I be successful in the world of the fathers' ; verily he is successful in the world of the fathers.

Let us see some of the points mentioned here in simpler language. For ensuring the acquirement of cattle for the *Yajamana* or patron financing for the sacrifice, the altar is to be made

6. B.B. Datta SS. 20.

of 'metres' (*chanda*). Hence such an altar is called *Chanda-sciti*. For ensuring heaven for the said patron, the altar is to be built in the shape of a falcon (*Syenaciti*), or, perhaps alternatively, also in the form of a heron (*Kanka-citi*). For ensuring "support in the four quarters" for the sacrificer, the altar is to be built in the shape of a certain species of bird called *alaja* (*Alajaciti*). For the annihilation of the present rivals, the altar is to be built in the shape of the "forepart of the poles of the chariot" or *prauga*, i.e. in the shape of an equilateral acute-angled triangle (*Praugaciti*). For the annihilation of the rivals both present and future, the altar is to be built in the shape of two such triangles joined together at the base (*Ubhayata-praugaciti*), though also an altar made in the shape of the chariot-wheel (*Rathacakraciti*) seems to have been recommended for the same purpose. An altar built in the shape of the funeral pyre (*Smasanaciti*) is recommended to ensure for the sacrificer the attainment of "the world of the fathers". And so on.

In the passage of the *Taittiriya Samhita* just quoted, there seems to be a thin attempt no doubt of connecting the different altar-shapes with the different desires these are supposed to fulfil. But the logic connecting the two is clearly arbitrary, or based at best on magical imagination, more than which is evidently not needed for the priestly purposes. In short what all this means is that the priests wanted the *Yajamana*-s or rich patrons financing for the sacrifices to believe that the sacrifices performed with fire-altars of specific designs ensured the fulfilment of the desires the rich patrons then cared for—desires for obtaining cattle, food, annihilation of rivals, attainment of heaven, and so on.

For our present discussion we have to note here specially one point. So far as the magical beliefs are concerned, there is evidently no need for any mathematics. But it is different when it comes to the question of the physical construction of the fire-altars. The *Yajurveda* text (*Taittiriya Samhita*) just quoted seems on the whole satisfied with the general prescription that certain shapes of the fire-altars magically ensured the fulfilment of certain desires. But such formulations in general terms evidently failed to satisfy the priests or priestly corporations perhaps of the later times. There grew among them the further demand that the fire-altars had to satisfy a

lot of further details. Thus, for example, each altar had to be constructed with a specific number of bricks arranged in a specific manner and answering to very precise sizes. At the present stage of research, it may be premature to venture any hypothesis as to how, where and why such detailed demands grew among the priests. But judging from the circumstances that in the *Sulva-sutra*-s the authority of the *Brahmana* texts is usually mentioned in justification of the demands for details, it may not be wrong to presume that the demands grew during the period of the *Brahmana*-s.

We can perhaps have from Eggeling's analysis of the general trend of the *Brahmana*-s some clue to the tendency of this. The addition of all sorts of complicated details to the sacrifical performances could make these extremely awe-inspiring, and hence conducive to the hierarchical aspirations. As he[7] puts it,

> The *Brahmanas*, it is well known, form our chief, if not our only, source of information regarding one of the most important periods in the social and mental development of India. They represent the intellectual activity of a sacerdotal caste which, by turning to account the religious instincts of a gifted and naturally devout race, had succeeded in transforming a primitive worship of the powers of nature into a highly artificial system of sacrificial ceremonies, and was ever intent on deepening and extending its hold on the minds of the people, by surrounding its own vocation with the halo of sanctity and divine inspiration. A complicated ceremonial, requiring for its proper observance and consequent efficacy the ministrations of a highly trained priestly class, has ever been one of the most effective means of promoting hierarchical aspirations. Even practical Rome did not entirely succeed in steering clear of the rock of priestly ascendancy attained by such-like means.

We have indeed some idea in this of the possible motivation behind the priestly tendency to make the sacrifices—inclusive of the construction for their altars—highly complicated. But the motivation itself is of no relevance for our understanding of the mathematical contents of the *Sulva-sutra*-s, for the simple reason that this mathematics does not follow from it.

What we are trying to argue and reemphasise is that the discussion of the fire-altars needs to be understood from two different standpoints. The first is the standpoint of the magico-

7. Eggeling SBE, Vol. XII. intro. pp. ix-x.

religious beliefs associated with these. The second is the standpoint of technology. For the second, the crucial question is : How exactly to construct the altars of specific shape, specified size and by using a definite number of bricks and how to vary the shape of the altars without changing their area, and so on.

The technicians—and the technicians alone—were competent to answer this question, and while answering it, they had to develop a significant amount of mathematical knowledge, or at last depend upon it.

It is interesting to note that the internal evidences of the Vedic tradition itself virtually admit this. The evidences are two-fold—positive as well as negative. Positively speaking, there are admissions within the Vedic tradition (or the tradition fully endorsed by Vedic orthodoxy) that though the Vedic priests, in their priestly capacity, wanted to have various complicated brick-structures constructed as fire-altars, they were also aware of the simple fact that for the physical construction of these structures it was necessary to depend on the know-how of the manual workers like the brick-makers, masons and architects. Negatively, the Vedic priests also suggested ways of ensuring the fulfilment of the same magico-religious designs while at the same time completely by-passing the problem of the physical construction of the brick-structures, apparently because they were also aware of the fact that skilled technicians for the purpose were not readily available.

4. "THUS WE ARE TOLD"

Reviewing the *Sulva-sutra*-s Thibaut observes, "But the chief interest of the matter does not lie in the superstitious fancies in which the wish of varying the shape of the altars may have originated, but in the geometrical operations without which these variations could not be accomplished."[8]

Surprisingly enough, in a sense this seems to be true also of the actual builders of the brick-structures whom we meet in the *Sulva* texts. Not that they expressed any doubt concerning the magico-religious efficacies imputed to the different altar

8. G. Thibaut in SHSI, Vol. II, 419-20

designs by the Vedic priests. It is inconceivable that they could have used the expression "superstitious fancies" for such beliefs, as Thibaut does. Nevertheless, for all that we can infer from the internal evidences of the *Sulva-sutra*-s, these technicians looked at such beliefs as belonging to the province of the "others", not their own. As for themselves, they took an absorbing interest only in the technological problems involved in physically constructing the brick-structures, in trying to solve which they developed their geometry and this for the simple reason that without geometry these technological problems could not be solved.

In the texts, therefore, we frequently come across expressions implying "Thus we are told" or "Such is the authoritative instruction", very clearly indicating that the instructions themselves were outside the main scope or the main theme of the *Sulva* texts. These are simply taken for granted and the main purpose of the texts is to explore ways for successfully executing these instructions.

This is virtually admitted by B. B. Datta, who otherwise subscribes fully and strongly to the most orthodox Vedic beliefs. After giving "in brief, a resume of the more salient points in the elaborate and minute in details specifications of the shape and size of the principal sacrificial altars and of the geometrical knowledge presupposed in their construction", he finds it necessary immediately to add :[9]

> What should be particularly emphasized now is the fact that those specifications are not due to the authors of the *Sulba* themselves. They do not even pretend to make any such claim. On the other hand, they have often and then expressly admitted to have taken them from earlier works. We, in fact, find that numerous passages of *Baudhayana* and *Apastamba Sulba* dealing with the spatial magnitudes of sacrificial altars as well as with the methods of their construction, end with the remark *iti vijnayate* [or 'it is known', 'it is recognised or prescribed (by authorities)]. Sometimes *iti abhyupadisanti* ('thus they teach') or *iti uktam* ('it has been said'), is used in the same sense. It has been rightly pointed out before by Garbe that all those passages of *Apastamba* are literal quotations from the *Taittiriya Brahmana* or from the *Brahmana*-like portions of the *Taittiriya Samhita* or *Aranyaka*. That is exactly true also of the similar passages of Baudhayana. This writer is occasionally more explicit about his sources.

Expressions like *iti vijnayate, iti abhyupadisanti, iti uktam,* etc. which frequently occur in the *Sulva* texts, are exceedingly interesting. These clearly imply that "what is to be done" is prescribed by "others", rather than the technicians and mathematicians whom we meet in the texts themselves. Thanks to the highly competent textual exploration by scholars like Garbe, we have also a clear idea of who these "others" were : we meet them in the priestly manuals *par excellence* like the recensions of the *Yajurveda* and more particularly in the *Brahmana*-s. It needs at the same time to be noted that the authorities in such priestly manuals are quoted in the *Sulva-sutra*-s *not in the context of the technological and mathematical questions discussed in the texts but only in the context of what is being dictated to them or of what they are asked to execute by the priests, leaving the technological as well as the mathematical problems of the actual execution of the work to be solved by them.*

5. AN EXAMPLE : BAUDHAYANA'S PROCEDURE

We shall mention here only one example of this, though adding that this is fairly typical of the major *Sulva* texts.

The oldest and by far the most important of these texts for the purpose of understanding the making of mathematics in ancient India is the *Sulva-sutra* associated with the name of Baudhayana. In this, the expression *vijnayate* signifying what is prescribed by the priestly sources first occurs as the sixtyfifth *sutra* or aphorism of the first chapter. It is, therefore, relevant to have a brief idea of the following points :

(i) What is discussed in the preceding sixtyfour *sutra*-s or aphorisms which refer to no authoritative instruction whatsoever may be assumed by us as characteristic contribution of the maker or makers of the mathematical contents we have in the text itself.

(ii) What actually is the nature of the authoritative instruction coming down to Sulva text and what moreover is the real source of this authoritative instruction.

(iii) What is discussed in the subsequent *sutra*-s intended to solve the problems of the actual execution of the authoritative instruction.

After stating in the first *sutra* that the purpose of the work is to discuss the questions concerning the construction of the

fire-altars, the *Baudhayana Sulva-sutra* asserts in the second *sutra* that for this purpose it is necessary at once to be clear about the units of measurement. Thus it opens with an account of linear measurement on which all the calculations in the text are based. The basic unit for this is called an *angula*, literally "the finger", which is specified by the *Arthasastra*[10] as "the maximum width of the middle part of the middle finger of an average person". J.F. Fleet[11] gives its modern equivalent as 0.75 inch (= 19.049 mm.), though V.B. Mainkar[12] calculates it to be 17.78 mm.

However, evidently for the purpose of finer calculations, our text adds that an *angula* is divisible into 14 *anu*-s or 34 *tila*-s. The mathematical utility for such sub-division is discussed by Thibaut.[13] For our present purpose let us have the table of linear measurement of the *Baudhayana Sulva-sutra*, which we have up to 21st *sutra* of the text and to which we shall have to refer repeatedly for understanding the mathematical calculations in it.

Here is Baudhayana's table of linear measures :

1 *angula* = 14 *anu*-s or 34 *tila*-s
1 "Small" *pada* (*ksudrapada*) = 10 *angula*-s
1 *pradesa* = 12 *angula*-s
1 *prtha* or 1 *uttarayuga* = 13 *angula*-s
1 *pada* = 15 *angula*-s
1 *isa* = 188 *angula*-s
1 *aksa* = 104 *angula*-s
1 *yuga* = 86 *angula*-s
1 *janu* = 32 *angula*-s
1 *samya* or 1 *bahu* = 36 *angula*-s
1 *prakrama* = 2 *pada*-s (i.e. 30 *angula*-s)
1 *aratni* = 2 *pradesa*-s (i.e. 24 *angula*-s)

10. *Arthasastra*, ii. 20. 7.
11. J.F. Fleet in JRAS, 1912, 229-239.
12. V.B. Mainkar in FIC, 147.
13. Thibaut in SHSI, II, 433. Taking *tila* as "Sesame grains", 34 of this "put together with their broad sides" makes a much longer length. Hence it is better to accept Thibaut's interpretation that *tila* here is taken in some other technical sense required for finer calculations.

1 *purusa*	=	5 *aratni*-s (i.e. 120 *angula*-s)
1 *vyama*	=	1 *purusa* (i.e. 120 *angula*-s)
1 *vyayama*	=	4 *aratni*-s (i.e. 96 *angula*-s)

After enumerating these units of linear measures, our text passes straightway to formulate a number of purely geometrical problems and offers their solutions from an essentially practical point of view—i.e. the point of view from which a craftsman or technician tries to solve these, having at his disposal nothing more than such simple equipments like the cord and the pole. To put in current terminologies these problems (and propositions) are :

1. How to construct (or draw) a square[14] the length of its side being given? The text gives two methods for the purpose, adding subsequently also a third one.
2. How to construct an oblong or a rectangle (*dirgha-caturasra*), its length and breadth being given.
3. The proposition that the square on the diagonal (*aksnaya*) of a given square is twice as large as that of the given square.
4. To construct a square whose area is three times the area of a given square. The square on the diagonal of an oblong (rectangle) is equal to the sum of the two squares on the two sides. This is shown in the cases of the oblongs the two sides of which are (a) 3 and 4 ; (b) 12 and 5 ; (c) 15 and 8 ; (d) 7 and 24 ; (e) 12 and 35 ; (f) 15 and 36. This, it may be noted, is in essence the proposition usually associated with the name of Pythagoras, though in our text we have hint also of the formulation of the proposition in general terms.
5. The way of making a square equal in area to the combined areas of two other squares of different sizes.
6. The way of making a square having an area equal to the difference of two given squares.
7. To construct a rectangle (or an oblong) whose area is equal to the area of a given square.

14. The more exact term for square is *samacaturasra*, which occurs in i.52 of the text.

8. To construct a square whose area is equal to that of a given rectangle (or an oblong).
9. The way of transforming a square into an isosceles trapezium, whose shorter side is given as lesser than the side of the square.
10. To construct a triangle equal in area of a given square.
11. To construct a rhombus equal in area of a given square.
12. The way of turning a square into a circle.
13. The way of turning a circle into a square.

Modern scholars like Burk, Thibaut, Datta and others—and following them recently also S.N. Sen and A.K. Bag—have extensively discussed the mathematical knowledge required to solve these propositions—knowledge which is already contained in the Sulva texts, though as to the texts themselves, composed as these were in cryptic aphoristic style, we have often to depend on their commentaries for a fuller appreciation of this mathematics. However, it would require long digression from our main argument to go here into the details of this mathematics. For purposes of procedural advantage, therefore, we have given it in the form of a separate appendix. The readers are thus referred to Appendix I of the present work, which is prepared by Professor Subinoy Ray of the Department of Mathematics, St. Paul's College, Calcutta.

For what we have been discussing here, one point needs immediately to be noted and re-emphasised. Beginning with the enumeration of the units of linear measures and upto the geometrical theme we have just quoted, our text finds no need whatsoever to mention or quote any authority or use the typical expression like *vijnayata* etc., implying 'thus is being told' or 'such is the authoritative instruction' etc. What is discussed upto this point is mathematics and mathematics alone.

Besides, it refuses to allow this mathematics to be in any way mixed up with the priestly view of the efficacy of the different brick-structures, which in our eyes appears to be totally arbitrary or fanciful, though it might have formed part of the priestly beliefs. One obvious reason for this strict separation of mathematics with the priestly ideology is that the allegedly mystical or mysterious imports that constitute the essence of their dictations do not and cannot agree with the strict rigour and accuracy required by the mathematical calculations. So

the two are best kept separated. At the same time, whatever have been the motivations of the priests to get altars constructed with peculiar shapes and sizes, those to whom come down the dictations of physically constructing these, were well-aware of the mathematical equipment needed for the purpose. Hence our text begins with this. In any case, it is a remarkable feature of the *Baudhayana Sulva-sutra* that so far as it discusses mathematics, it restricts itself to mathematics alone, and therefore remains aloof from the magico-religious beliefs.

6. MATHEMATICS TO MEET THEOLOGICAL TWADDLE

Only after the mathematical discussions essential for technological requirements are over, the text mentions something that really belongs to the priestly province, i.e. theme of the sacrificial ritual. Significantly, the text also uses for the first time the expression *vijnayate* or 'thus we are being told', in connection with this theme. Here is how the text reads :

"The place of the *ahavaniya* fire is to be found by starting from the *garhapatya* fire (and measuring towards the east).

"In this matter, following is the instruction (*vijnayate*).

"The Brahmin is to construct the (*ahavaniya*) fire at a distance of eight *prakrama*-s (i.e. $8 \times 30 = 240$ *angula*-s) (to the east from the *garhapatya*), the Rajanya (Ksatriya) at the distance of eleven, the Vaisya at the distance of twelve.

"With the third part of the length (of the distance between *ahavaniya* and *garhapatya*) he is to make three squares following upon each other (touching each other) ; the place of the *garhapatya* is in the north-west corner of the western square, the place of the *daksina agni* (=*anvaharya-pacana*) in the south-east corner of the same square ; the place of the *ahavaniya* in the north-east corner of the eastern square."[15]

What are the fire altars for which the names chosen are *ahavaniya*, *garhapatya* and *daksina*? Why are the distances and relative directions recommended for them? These are questions completely outside the scope of our Sulva texts and hence the *Baudhayana Sulva-sutra* shows no interest whatsoever in

15. *Baudhayana Sulva-sutra* 1.64-67. The references to the Sulva text are based on Thibaut's edition of it originally published in the *Pandit* 1874/5-1877.

raising these. We are simply told that such and such are the authoritative instructions and the text is concerned only with the technique of carrying out the instructions. The problems of "why" and "how" are different altogether and the *Sulva* text is concerned with the second and the second alone.

Impelled by curiosity, however, one may be inclined to ask : wherefrom do the instructions actually come? As is only to be expected, the source of the instructions is the priestly literature. In the case under consideration, it is the *Satapatha Brahmana*. Impelled by natural curiosity, again, one may be inclined to go back to this source to see how exactly are the instructions expressed there. When one does this, one cannot but have the feeling of entering into a different thought world altogether—a realm of capricious assumptions strung together at best by a thin string of pure magical belief. The *Satapatha Brahmana* simply declares :

"He may lay it (the Ahavaniya) down at the distance of eight steps (from the Garhapatya) ; for of eight syllables, doubtless, consists the *gayatri* : hence he thereby ascends to heaven by means of the *gayatri*.

"Or he may lay it down at the distance of eleven steps ; for of eleven syllables, indeed, consists the *tristubh* : hence he thereby ascends to heaven by means of the *tristubh*.

"Or he may lay it down at the distance of twelve steps ; for of twelve syllables, indeed consists the *jagati* : hence he thereby ascends to heaven by means of the *jagati*. Here, however, there is no (fixed) measure : let him, therefore, lay it down where in his own mind he may think proper. If he takes it ever so little east (of the Garhapatya), he ascends to heaven by it."[16]

There is reallv nothing in it than what Max Muller aptly describes as a 'theological twaddle'—twaddles that crowd the *Brahmana* literature. It requires an extra-ordinarily inflated veneration for the Vedas to see in this anything having even a semblance for any enthusiasm for science. What is palpable instead is the anxiety to tempt the sacrificer to move rather easily to the heavenly region : he may do it only by moving either eight or eleven or twelve steps. Remarkably enough,

16. *Sat. Br.* i. vii. 3. 23-25.

while prescribing these the priests apparently forget—or perhaps conveniently overlook—what they themselves develop as 'metrical science' or *chanda*, evidently required by the oral tradition of the pre-literate poets whom we meet in the *Rgveda*. In their own understanding of the metres, the Gayatri does not actually consist of only eight syllables ; the number of syllables in this metre being twentyfour. So also are the cases of the metres called Tristubh and Jagati which, instead of consisting of eleven and twelve syllables, actually consist of fortyfour and fortyeight syllables. The priests in the *Satapatha Brahmana* must have been well-aware of this. Could it, then, be that in prescribing the instructions quoted, they were deliberately shortening the standard number of the syllables in the metres (by counting only the number of the syllables contained in the first line of each metre) to spare the sacrificer the trouble of walking longer to reach the heaven ?

In any case, there also remains an obvious arbitrariness in the instruction as mentioned in the *Satapatha Brahmana*. If it is possible to reach the same results by allowing only 'eight steps' as the distance between the two fire altars, why do the priests bother to mention alternative prescriptions of eleven and twelve steps ?

It is for the specialists in the Vedic ritual literature to find out if there is any authority intervening between the *Satapatha Brahmana* and the *Baudhayana Sulva-sutra*, who notices such an arbitrariness and wants to remove it by suggesting that the three alternatives proposed are really intended for sacrificers belonging to the three upper castes—Brahmins, Rajanyas and Vaisyas—i.e. giving the instructions the form in which these reach the Sulva text ?

But whatever the case may be, the point to be noted is that such prescriptions, *as ritual prescriptions*, have nothing to do with the actual problems discussed in the *Sulva* texts, beyond the bare admission, of course, of mentioning *what is required to be done*. The distinctive theme of the *Sulva* texts is different altogether, namely *how is this to be done*? This difference is crucial for our understanding of the history of science in ancient India. Whatever might have been the motivation of the priests dictating certain orders to be carried out in the interest of their sacrificial ritual, that has no bearing at all for the making of science in ancient India as found in the *Sulva* texts. These

texts take an exclusive interst in the technological-mathematical problems without solving which the dictations that came down to the technicians in the texts could not be executed in actual practice, with as much precision as was perhaps feasible in the ancient context.

7. B.B. DATTA'S ANALYSIS OF A PROBLEM

Compared to many other technological and mathematical problems sought to be solved in the *Sulva* texts, the problem that we have just mentioned, *viz.* that of ensuring the precise distance and relative directions of the three fire altars, may appear to be somewhat simple. Really speaking, however, it may be an error to take an over-simplified view of the whole thing, for the *Sulva* text actually suggests three different methods of solving the problems, from the analysis of which B.B. Datta is inclined to see the prodigious first step—though understandably only with approximate success according to our modern standards—taken to work out the value of $\sqrt{5}$ and $\sqrt{2}$. We quote him[17] at some length :

There seems to have been a serious attempt, though without much success, to find an approximation to the value of the surd $\sqrt{5}$. The occasion was to define clearly the relative positions of the three principal and oldest known fire-altars, viz., the Garhapatya, Ahavaniya and Daksina. Baudhayana's rules to determine their positions are these :

'With the third part of the length (i.e., the distance between the Garhapatya and Ahavaniya) describe three squares closely following one another (from the west towards the east) ; the place of the Garhapatya is at the north-western corner of the western square ; that of the Daksinagni is at its south-eastern corner ; and the place of the Ahavaniya is at the north-eastern corner of the eastern square.' (BSS. i. 67).

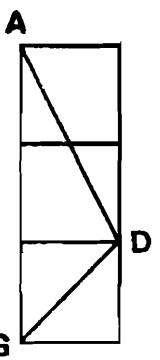
'Or else divide the distance between the Garhapatya and Ahavaniya into five or six (equal) parts ; add (to it) a sixth or seventh part ; then divide (a cord as long as) the whole increased length into three parts and make a mark at the end of two parts from the eastern end (of the cord). Having fastened the two ends of the cord (to the two) poles at the extremities of the distance between the Garhapatya and Ahavaniya, stretch it toward the south, having taken it by the mark and fix a pole at the point reached. This is the place of the Daksinagni'. (*BSS.* i.68).

'Or else increase the measure (between the Garhapatya and Ahavaniya) by its fifth part; divide (a cord as long as) the whole into five parts and make a mark at the end of two parts from the western extremity (of the cord). Having fastened the two ties at the ends of the east-west line stretch the cord towards the south having taken it by the mark and fix a pole at the point reached. This is the place of the Daksinagni' (*BSS.* i.69).

The second is also given by Apastamba. A rule leading to the same result as the first one above, though defined differently, is stated by Katyayana and Manu. Katyayana has specified the relative positions of the three fire-altars also in a new way:

'Divide the distance between the Garhapatya and Ahavaniya into six or seven parts; add a part; then divide (a cord) equal to the total increased length into three parts, etc.' (*KSS* i. 27).

The rest of this rule is the same as the latter portion of the second rule above and hence need not be mentioned.



Let b denote the distance beetween the Garhapatya and Ahavaniya, that is AG. Then from the different specifications given above we obtain the following values for AD and GD:

$$\text{AD} = \tfrac{b}{3}\sqrt{5},\ \tfrac{4}{5}b,\ \tfrac{7}{9}b,\ \tfrac{16}{21}b,\ \tfrac{18}{25}b$$

$$\text{GD} = \tfrac{b}{3}\sqrt{2},\ \tfrac{2}{5}b,\ \tfrac{7}{17}b,\ \tfrac{9}{21}b,\ \tfrac{12}{25}b$$

If it be assumed that the relative positions of the three fire-altars were meant to be the one and the same, in all cases though expressed differently, then we shall have the following approximations to the values of $\sqrt{5}$ and $\sqrt{2}$:

$$\sqrt{5} = 2\tfrac{2}{5},\ 2\tfrac{1}{3},\ 2\tfrac{2}{7},\ 2\tfrac{4}{25}$$
$$= 2.4,\ 2.333\ \ldots,\ 2.285\ \ldots,\ 2.16.$$

$$\sqrt{2} = 1\tfrac{1}{5},\ 1\tfrac{1}{6},\ 1\tfrac{1}{7},\ 1\tfrac{11}{25}$$
$$= 1.2,\ 1.166\ \ldots,\ 1.142\ \ldots,\ 1.44.$$

Since according to modern calculation $\sqrt{2} = 1.414213 \ldots$ and $\sqrt{5} = 2.23607 \ldots$ none of the above values can be said to be a fair approximation, perhaps except the values $\sqrt{5} = 2^2/_7$ and $\sqrt{2} = 1^{11}/_{25}$ which are correct up to the first place of decimals.

It is for the mathematicians to judge if there is any tendency to over-rate the mathematical potentials in the *Sulva* texts in the analysis of Datta just quoted. For us, however, there are other interesting points to note regarding what is dictated by the priests about the construction of the three relatively simple fire altars called Garhapatya, Ahavaniya and Daksina.

Serious problems are created by what the priests further dictate about the construction of the Garhapatya fire altar. Thus, for example, in the *Baudhayana Sulva-sutra* (ii. 61 ff.) we read :

"It is of the measure of *vyayama*. This is the instruction (*vijnayate*) for the construction of the Garhapatya.

"According to one authority, it (Garhapatya) has the form of a square (*caturasra*).

"According to other authorities, it has the form of a circle (*parimandala*)".

All this, as Thibaut explains, means : "The Garhapatya is either a square the side of which is one *vyayama* long or a circle of the same area." Preferring not to ignore any of the two authoritties, the *Baudhayana Sulva-sutra* takes both with equal seriousness. This means that the text is immediately confronted with two problems :

First, how to construct a square the area of which is one *vyayama* X one *vyayama*. It needs to be noted that one *vyayama* = 4 *aratni*-s, each *aratni* = 2 *pradesa*-s and each *pradesa* – 12 *angula*-s. That is, one *vyayama* = 96 *angula*-s. The first problem, thus, is to draw a square with an area of 96 angula-s X 96 angula-s.

Secondly, since the shape of the Garhapatya is required to be either a square or a circle though *without affecting its size*, there is also the problem of converting a square into a circle, or, to be more specific, converting a square of 96 *angula*-s × 96 *angula*-s (i.e. 9216 sq. *angula*-s) into a circle having exactly the same area, and *vice versa*.

From the mathematical viewpoint the problem of circling a square or squaring a circle was not an easy one—in fact it is later found to be an impossible one.[18] But the *Baudhayana Sulva-sutra* cannot evade it, because it reoccurs in the context of the fire-altar called Dhisnya which, according to the priestly dictation, must have the shape of either a square or of a circle evidently of the same size.[19]

How far the mathematicians in our *Sulva* texts successfully solve the problems of circling a square or of squaring a circle is, of course, a different question. Eminent modern scholars like Burk, Thibaut, Datta and others have tried to go into it in some detail, though without necessarily agreeing with each other. Evidently enough, while re-examining this problem in the general background of modern mathematical knowledge, the scholars remain exposed to the dual risks of either over-rating or under-rating the scientific potentials in these ancient texts using the ancient style of cryptic mnemonical aphorisms. Since these aphorisms by themselves are often not explicit in what precisely these are intended to convey, our scholars are understandably often obliged to depend more or less heavily on the later commentators on the *Sulva* texts. Such a procedure, though methodologically somewhat inescapable, makes them exposed to another risk, namely that of historical anachronism, inasmuch as at least some of these major commentators—on their own admission—drew on much later mathematical works, like those of Aryabhata (born A.D. 476) and even Bhaskara II (born A.D. 1114), when mathematics in India takes a sharply new turn with intricate methods of new calculations, notwithstanding—as Thibaut shows—the survival in later Indian mathematics of some ancient nomenclature like *varga, karani,* etc. of the *Sulva* texts. But all this does not and must not mean that the mathematical achievements recorded in the Sulva texts, specially as judged in their historical context, cannot but be considered as highly remarkable, whatever might have been the intrinsic worth of priestly beliefs the demands of which this mathematics was required to meet.

To sum up the discussion so far : The starting point for our understanding of the *Sulva* texts, is to differentiate bet-

18. D.E. Smith HM II. 302f.
19. *Baudh. S. S.*, ii. 73.

ween two questions. First: *What* is to be done? Secondly: *How* is this to be done? The first of these two questions is really extrinsic to the essential theme of the *Sulva* texts which concentrate—and concentrate on the whole exclusively—on the second question. The *Sulva* texts themselves make this abundantly clear by repeating over and over again typical expressions like *vijnayate, iti abhi-upadisanti* etc., implying that what is to be done is dictated by sources external to the texts themselves. Significantly, such expressions invariably occur in the context of the ritual prescriptions connected with the nature of the brick-structures called fire altars. This, in other words, means that the dictations come from the Vedic priests, to whose literature—specially the *Taittiriya Samhita* and the *Satapatha Brahmana*—the priestly dictations are naturally traced by the modern scholars, and sometimes even frakly admitted by the Sulva texts themselves.

8. ROLE OF THE TECHNICIANS

Commenting on the methods suggested by the *Sulva-sutra*-s of squaring the circle and *vice versa,* Thibaut says, "Theirs was not the love of disinterested research which distinguishes true science, nor the inordinate craving of undisciplined minds for the solution of riddles which reason tells us cannot be solved; theirs was simply the earnest desire to render their sacrifice in all its particulars acceptable to the gods, and to deserve the boons which the gods confer in return upon the faithful and conscientious worshipper".[20]

Such an observation seems to be in need of a number of amendments from different standpoints.

A specialist in Vedic studies would perhaps prefer to look back at the Vedic rituals as but magic techniques for obtaining the desired results by the intrinsic efficacy of the ritual acts and spells, leaving practically no scope for any god or gods to come effectively into the picture. The Vedic literature—particularly the earliest one or the *Rgveda*—mentions a whole host of gods and demi-gods no doubt. In the ritualist

20. Thibaut, in SHSI, 445.

view, however, they are denuded of divine functions like conferring the boons etc. As is rather well-known, the Purva-mimamsa philosophy—which is the direct outcome of the theoretical presuppositions of the standpoint of the Vedic ritualists—finds it necessary not only to deny the existence of god but also of going to the extent of arguing that the names of the famous gods of the ancient Vedic pantheon are mere words after all, having efficacy only as forming parts of the magic spells. As Nilakantha Sastri, after reviewing the Purva-mimamsa view of the Vedic gods, observes : "Is the sound 'Indra' then, all that is left of the great Vedic hero or god? It may be so, Mimamsa is not concerned with that, in effect it does not know."[21] This is true, though not the whole truth. Jaimini in his *Mimamsa-sutra* and also his commentator Sabara elaborately and very strongly argue that what is important above all is the ritual act and the names of the gods have no more function in it than forming parts of the right spells.[22] Thus, on the whole, the Christian or quasi-Christian view of God which Thibaut virtually imputes to the Vedic priests is hardly acceptable from their expressed standpoint.

Secondly—and this is much more serious an objection to the observation of Thibaut—he takes it for granted that genuine science is in fact only a disinterested pursuit of pure knowledge. Though such an elitist understanding of science intended to keep it aloof from any contribution to it of the manual workers—the craftsmen and the technicians—had once been popular with the historians and philosophers of science, it is exploded today by the more objective researches of Joseph Needham, J. D. Bernal, Benjamin Farrington, Gordon Childe and many others. And long before them, Prafulla Chandra Ray had very convincingly shown that by far the most important factor accounting for the decline of scientific spirit in India had been the caste system which prevented the elites to draw upon the experiences of the manual workers relegated to the lower strata of the society, which evidently implies that science draws its real nourishment from manual workers.

21. Nilkantha Sastry in *IA*, vol. 50. 241.
22. *Mimamsa-sutra*, iii. 344 ; viii. 1.32-34 ; ix, 1.10 etc., and Sabara thereon.

As a matter of fact, one of the main interests of the *Sulva-sutra*-s in the history of science is that these make it very palpable that the mathematics therein is inconceivable without being connected with the contributions of the manual workers —the craftsmen and the technicians, specially the brick-makers and the brick-layers. When, therefore, Thibaut observes about the makers of mathematics in ancient India that "theirs was not the love of disinterested research", he tells us something of fundamental importance about them, though obviously not in the sense in which he himself means it. Working under the influence of the usual assumption that this mathematics was the creation of the Vedic priests, Thibaut assumes that it was the result of the attempt to please the gods with sacrifices, whereas the fact seems to be that the priests had no more role in the matter than dictating *what is to be done*, whereas the mathematics we have in the texts was the outcome of the theoretical requirements of those who were confronted above all with the question of *how is this to be done*.

9. ADMISSION IN THE VEDIC TRADITION

That for the actual construction of the brick-structures—called *agni* or *citi* in the priestly terminology—technicians outside the circle of the Vedic priests were required is virtually admitted by the Vedic tradition itself. In the appendix to the *Katyayana Srauta-sutra* we read that those who were required to execute 'what is to be done' need to have the following qualifications :

sastrabudhya vibhagajnah parasastra-kutuhalah/
silpibhyah sthapatibhyah ca adadita matih sada//[23]

"One who is engrossed in the subject, knows the technique of division, has the curiosity to know the science of the others and always pays proper attention to the work of the artisans and architects."

The word *vibhagajnah*, literally "one who knows the technique of division", could have been an old way of referring to

23. S.D. Khadilkar's, *Katyayana Sulva Sutra* (Poona : 1974). This occurs as the sixth verse of chapter vii. That seeems to be a case of editorial oversight, for the sloka does not form part of the *Katyayana Sulva-sutra*. See, B.B. Datta SS 4.

those that had knowledge of what we call geometry and allied calculations. But there is no scope at all to speculate on the meanings of *silpi* and *sthapati*, which clearly mean the artisan and architect. More interesting, however, is the expression *parasastra-kutuhalah*—"having curiosity to know the science of others." This seems to speak volumes. It is not easily conceivable that the priests, *as priests*, would admit the importance of any *Sastra* other than their own, i.e. their priest-craft, consisting mainly of ritual details, magical beliefs and theological or quasi-theological disputations. In the expression "having curiosity to know the science of others", it is tacitly admitted, however, that this is not enough for the purpose of the physical construction of the most complicated brick-structures with specific shapes and size. How can the priest, with all his claim to the most profound wisdom but equipped only with the knowledge of the priest-craft, at all confront the problem of the physical construction of the complicated brick-structures which require above all whole-time specialisation of the brick-makers, masons and architects?

Accordingly, the *Ramayana* also mentions that for the performance of the sacrificial ritual—priests apart—are required the following classes of persons: manual worker (*karmantika*), artisan (*silpakara*), carpenter (*vardhaki*), digger (*khanaka*) and mathematician (*ganaka*).[24] Evidently, it is not conceivable that the *Ramayana* specially in the form in which it comes down to us could flout the priestly norm, which, in other words, means that all this had implicit acceptance of the priest-class.

At the same time, the acceptance could have been rather grudging than enthusiastic, because according to the *Dharmasastra* norm— which, as already noted, was the creation of the same priestly corporations that produced the *Kalpa-sutra*-s —the social status of such manual workers is supposed to be low—certainly much lower than of the priests themselves.

An enthusiast for Vedic culture, in defence of the view that the Sulva mathematics could not but be the creation of the Vedic priests, may argue that there is nothing to prevent the assumption that a section of the Vedic priests might have developed an all absorbing interest in brick-making and brick

24. *Ramayana*. Balakanda, xii. 6-9; xiv. 26-28.

laying essential for the construction of the fire altars, and, drawn by the theoretical requirements of these technologies, could have been the makers of mathematics. Such an assumption, however, would necessitate the further assumption that these priests could do it *not in the capacity of priests in the real sense but in the capacity of craftsmen and technicians*—flouting for the purpose the Dharmasastra norm generally contemptuous of the manual workers.

But an interesting evidence of the *Mahabharata* seems to pour cold water on such an enthusiasm.[25] According to this the king wanting a sacrifice to be performed, got priests (*rtvij*) to measure the space for altar-construction and employed learned Brahmins with specialised knowledge of priest-craft to construct the altar. Eventually, however, it was realised that there was some bungling somewhere about the whole procedure—specially about matters concerning measurements—which would have frustrated the entire sacrificial performance It is, however, of crucial importance to note that this bungling was detected not by the priests themselves but by a mason (*sthapati*) well-versed in architectural techonology (*vastu-vidya*). Thus the legend admits, though negatively, that something more than mere specialisation in priest-craft was needed for the construction of the structures called sacrificial altars and this was the know-how of the masons and architects. To this needs to be added only one point. The *Mahabharata* as a whole, in the form in which it reaches us, is accepted as something sacred by the orthodox Vedic tradition and every legend in it is fully endorsed by Vedic orthodoxy.

10. EVADING THE ENTIRE PROBLEM OF THE PHYSICAL CONSTRUCTION OF THE BRICK-STRUCTURES

Let us begin by reiterating a simple point. In the Sulva texts, authoritative instructions concerning "what is to be done" indicated by expressions like *vijnayate*, *iti-abhi-upadisanti* etc. invariably come down from the priestly literature like the *Taittiriya-Samhita* and the *Brahmana*-s. But nowhere in these texts such expressions occur in the context of discussing the problem of "how is this to be done", though the discussion

25. *Mahabharata*, Adi-parva. LXI. 9 ff.

of the second constitutes the special peculiarity of the Sulva texts, inclusive of their mathematical contents. This peculiarity of the texts seems to give us the impression that if the Vedic priests are at all to be credited with the making of this mathematics, it could at best be in a very indirect sense, like the sense in which the god-kings of ancient Egypt wanted the pyramids to be constructed and thereby providing the stimulant for the making of mathematics among the actual architects, masons, engineers and others, to whom came down the task of the physical construction of the structures—construction that required the development of mathematical knowledge. But let us leave the problem of the assessment of this analogy to those that specialise in the history of ancient Egypt, for the possibility remains that the Egyptian god-kings were not so fully parasitical after all as were the Vedic priests—the latter subsisting only on the *daksina*-s or fees for performing the sacrifices in the interest of their rich patrons or *yajamana*-s and whose law-codes frowned upon manual labour on the part of the nobles and priests.

But there remains another important point to be noted in this connection. The dictation of "what is to be done" evidently presupposes the feasibility of its execution. To borrow an example often used in Indian philosophical literature, you cannot dictate anybody to get oil by pressing sand, because that is beyond feasibility. The construction of the complicated brick-structures required by the priests, therefore, must have been feasible, in order not to make the dictation meaningless. This means that there must have been technicians capable of physically constructing such brick-structures. There is no difficulty in assuming the existence of such technicians during the period of First Urbanization, or that of the Mature Harappan Culture, when highly sophisticated brick-technology was an accomplished fact. But it is not easy to assume ready availability of such technicians during the period intervening the two urbanizations, i.e. during what is often referred to as the "Dark Age" or "Dark Period" by the archaeologists—a period to which the Sulva texts belong. However, since the consideration of basic feasibility wants us to assume that there were technicians capable of executing what was dictated to them, the availability of at least some such techinicians even in this period cannot be denied outright.

At the present stage of research, it is of course impossible to ascertain their identity. One is tempted to presume that they could be stray stragglers of the Harappan technicians, though how the technique could survive among them in spite of falling into general disuse is not easy to understand. One may perhaps hope that with the increasing interest of the recent archaeologists to explore and excavate the Late Harappan and Post Harappan Sites, some new light may eventually be thrown on the problem. For the present, however, it remains one of the many unresolved problems of ancient Indian history.

What is not obscure, however, is another point. Admitting the existence of some stray technicians capable of actually constructing the complicated brick-structures in the period under consideration, it is not easy to conceive that their services were readily available in the Vedic settlements for making the fire-altars. The Vedic priests must have been aware of this difficulty more than anyobdy else. Hence must have also been the need felt by them for bypassing the whole problem of the physical construction of the brick-structures, without affecting in any way their basic claim to the magico-religious efficacy of the structures themselves. The way in which they actually solved this problem appears to us as amazingly simple. Some imaginary structures could be as good as the physically constructed ones. This leads us to see their ingenuous theory of *chandascit* and *manomaya* or *manascit*.

Already in the *Taittiriya-samhita* it is declared, "He who desires cattle should pile a piling with the metres (*chandascit*) ; the metres are cattle ; verily he becomes rich in cattle."[26] But what is meant by this ? What is meant by *chandascit* ? Datta[27] gives a very lucid answer to this :

> In case of the Chandasciti, the *agnicit*, ('fire-altar builder') draws on the ground the Agni (altar) of the prescribed shape, ordinarily of the primitive shape of the falcon. He then goes through the whole prescribed process of construction imagining all the while as if he is placing every brick in its proper place with the appropriate *mantra*-s (spells). The *mantra*-s are, indeed, muttered but the bricks are not

26. *Taittiriya Samhita*, V. 4.11.1.
27. B.B. Datta SS. p. 3n.

actually laid. Hence the name Chandasciti, i.e. the *citi* or altar made up of *chandas* or Vedic *mantra*-s instead of bricks or loose mud pieces.

So that is not a real structure but the imaginary substitute for a structure, for the construction of which the entire problem of recruiting skilled craftsmen could be conveniently evaded, but, which, from the viewpoint of the priestly claims, could be equally efficacious in the matter of magically ensuring the financiers for the sacrifice a good deal of wealth—cattle having been the measure for counting wealth for the early Vedic peoples.

There are evidences to think that the priestly ingenuity of suggesting imaginary altars as substitutes for the physically constructed ones was not confined to this simple one.

Commenting on the *Brahma-sutra*[28] both Sankara and Ramanuja found it necessary to examine the view of the ritualists concerning what was called *manomaya* or *manascit*, literally "mind-made altars." Apparently, there was talk of a very large number of these in the priestly circles, because Samkara mentioned thirtysix thousand varieties of these! The names of some of these speak for themselves. Thus, we read of *vakcit*, literally 'altar made of the organ of speech' or, more simply, verbally constructed altar; *caksuscit*, literally 'altar made of the organ of vision', or, more simply, visually constructed altar; *srotracit*, literally 'altar made of the auditory organ', or, more simply, sound-made altar, etc.

The claim of the ritualists, intended to be examined by the *Brahma-sutra* was very lucidly put by Ramanuja[29]:

> That the altar built of thought is an optional substitute for the altars built of bricks, and of the nature of an action, appears therefrom also that the clause 'of these each one is as great as that previous one', explicitly transfers to the altars of mind, and so on, the powers of the previous altars made of bricks. All those altars, thus having equal effects there is choice between them. The altars of mind, and so on, therefore are auxiliary members of the sacrificial performance which they help to accomplish, and hence themselves of the nature of (ritual) action.

Not that Samkara and Ramanuja—or, for that matter, presumbaly also the author of the *Brahma-sutra*—subscribed to

28. *Brahma-sutra*, iii. 3.44 ff.
29. Ramanuja on *Brahma-sutra*, iii. 3.45. Tr. Thibaut, *SBE*, XLVIII, 669.

this view. The view is mentioned as a *purvapaksa*, i.e. the opponent's view intended only to be rejected. But the reason for this needs to be clearly noted. Samkara and Ramanuja, like the author of the *Brahma-sutra* itself, were opposed to the ritualistic view as such. In traditional terminology, they represented the *jnana-kanda* or "knowledge branch" of the Vedas, as constrasted with and sharply opposed to what was called the *karma-kanda* or "the ritual branch" of the Vedas. In other words, this was a controversy between the philosophical standpoint claiming to draw its sanction from the Upanisads and priestly standpoint in its restricted sense claiming to draw its sanction above all from the *Yajurveda* and *Brahmana*-literature. The view that the mind-made altars were suitable substitutes for brick-built altars was contested by Samkara and Ramanuja mainly because it formed part of the *karma-kanda* or the ritualistic standpoint of the Vedic priests. But what, indeed, could the priests do than to recommend such imaginary or mind-made altars as substitute for the brick-built ones, when the physical construction of the latter required highly skilled masons and architects not easily available in the Vedic settlements, which are archaeologically connected with the Painted Gray Ware sites unaware of brick technology?

The evidence for *chandascit* and *manascit* are, therefore, crucial. These prove that there was *no necessary connection between the physically constructed brick-structures and the magico-religious beliefs imputed to these by the Vedic priests.* Thus the know-how of the brick-constructions was not obligatory for the priests—whose priest-craft itself was so elaborate that it presumably required whole-time specialisation—notwithstanding the circumstance that the Sulva texts survive for us as appended to the manuals of the practising priests.

11. QUESTION OF VOCABULARY AND TERMINOLIGY

Further, certain internal evidences of the Sulva texts do not easily cohere with the view that these could be the creations of the Vedic priests. One of these is that of vocabulary and terminology. From this point of view where the Sulva texts most sharply turn away from the *Taittiriya-samhita* and even from the *Satapatha Brahmana*—is about the brick-names. Before passing on to discuss it, we may briefly note certain

other hints about the vocabulary of the Sulva texts suggesting or hinting more of the association with plebian craftsmen than the priestly elites.

The very word *Sulva* for rope or cord is so elitist-esoteric that in the whole range of Sanskrit literature it is difficult to come across it outside the titles of the texts. Within the texts, however, the word is never used, the cord or rope being referred to as *rajju*. This peculiarity of the texts is already noted by Thibaut who observes : "I may remark at once that the *sutra*-s themselves do not make use of the term *sulva* ; a cord is regularly called by them *rajju*."[30] What needs to be added to it is only a simple point. The ward *rajju* is in fact so plebian that it is the same also in Pali. A craftsman would have been easily familiar with it and use it as part of his own vocabulary rather than the word *sulva*, which was presumably current only among the priestly elites.

Another peculiarity of the texts which cannot be easily overlooked is the use of the word *atman* to mean the body and the body alone. In this matter, there is no scope whatsoever for any speculation to suggest a theological or philosophical alternative. In the Sulva texts the word *atman* is invariably used to mean the body in its crass physical sense. But this is not easily conceivable in the circle of the Vedic priests and their theologico-philosophers specially after the Upanisads, which Vedic orthodoxy wants us to accept as but appendices to the *Brahmana*-texts and in which the word *atman* acquires the sense of Pure Spirit or the Pure Soul with the vigorous emphasis that this soul must not be confused with the body. which is at best a temporary (but on the whole unfortunate) dwelling place for the soul.

One is almost tempted to see in the Sulva vocabulary the much-maligned philosophical view called *dehatmavada*, i.e. the view equating the *deha* or body with the *atman*. Such a view, as is rather well-known, is characteristic of the Lokayatas, a name that literally means "that which is prevalent among the people", or, as Samkara more explicity states, is characteristic of "the common uncultured mob" (*prakrtajanah*).[31] The

30. Thibaut, G. in SHSI II. 416.
31. D. Chattopadhyaya, *Lokayata*, 1-2.

technicians and craftsmen would easily belong to this category ; but it is inconceivable that the Vedic priests or their ideologues could come under it or accept even tacitly a philosophical view usually characteristic of them.

But more of the question of the general theoretical temper later. For the present let us have a brief survey of the view of bricks in the Vedic literature.

12. BRICKS IN THE YAJURVEDA : TAITTIRIYA SAMHITA

The word for brick in the Vedic literature is *istaka*. Though the controversy over the exact origin of the word is still going on, it may be rash for us to ignore outright the view of Przylusky and others[32] who strongly argue that it is Dravidian in origin, though eventually borrowed by the Vedic peoples. In any case, the fact is that the word is absolutely unknown to the *Rgveda* and, in the Vedic tradition, it first occurs in the *Yajurveda*. But the *Yajurveda* appears to be more interested in the mysterious or magical efficacy of the bricks than telling us what these things actually are. Here is a typical example of this from the *Taittiriya-samhita*[33] :

> May these bricks, O Agni, be milch cows for me, one, and a hundred, and a thousand, and ten thousand, and a hundred thousand, and a million, and ten million, and a hundred million, and a thousand million and ten thousand million, and a hundred thousand million, and ten hundred thousand million, and a hundred hundred thousand million ; may these bricks, O Agni, be for me milch cows, sixty, a thousand, ten thousand unperishing ; ye are standing on holy order, increasing holy order, dripping ghee, dripping honey, full of strength, full of power ; may these bricks, O Agni, be for me milkers of desires named the glorious yonder in yon world.

In such gambols of pure phantasy, it is difficult to see the physically made bricks, not to speak of the hint of brick technology in any significant sense. The desultory interest in the bricks as such can easily be judged from the use of the brick-names randomly connected with their magical potency which we read in the text. Here are just a few examples :

32. J. Przyluski in IHQ, Vol. VII, 735 f.
33. *Taittiriya-samhita.*, IV. 4. 11.

apanabhrt	or	'nourisher of *apana* (*Vayu*)' bricks.[34]
pranabhrt	or	'nourisher of *prana* or breath' bricks.[35]
asvini	or	'connected with Asvin (an asterism or the twin-god-Asvins)' bricks.[36]
vayasya	or	'*vayas* (? vigour)' bricks.[37]
brhati	or	'*brhati*-metre' bricks.[38]
valakhilya	or	'valakhilya (derivation doubtful)' bricks.[39]
aksayastomiya	or	'*aksaya* (? circuitous) + *stoma* (collection)' bricks.[40]
samyani	or	'*samyana* (= a mould ; a vehicle ; going together)' bricks.[41]
vyusti	or	'vyusti (= breaking of dawn ; increase ; prosperity)' bricks.[42]
nakasat	or	'nakasat (= sitting or dwelling in the sky)' bricks.[43]
pancacoda	or	'having protuberance' bricks.[44]
vikarni	or	'earless' bricks.[45]
svayamatrnna	or	'full of natural holes' bricks.[46]
sayuj	or	'united or comrade' bricks.[47]
bhuyaskrt	or	'augmenting or increasing' bricks.[48]
vrstisani	or	'rain-acquiring' bricks.[49]
asapatnya	or	'rival-removing' bricks.[50]
viraj	or	'ruling far and wide' bricks.[51]

34. *Ibid* IV. 3.3 see, Keith VBYS. p. 328 note 3.
35. See, Keith *Ibid.*
36. *Tait. Sam.* iv. 3.4. See Keith *Ibid*, 329, note 4.
37. *Ibid*, iv. 3.5, See Keith *Ibid* 330, note 6.
38. *Ibid.* iv. 3.7, see Keith. *Ibid.*, p. 331 note 4.
39. *Ibid.*
40. *Tait. Sam.* iv. 3.8. See. Keith, VBYS 332, note 1.
41. *Ibid*, iv. 3.10. See Keith *Ibid*, 333, note 2.
42. *Ibid*, iv. 3.11 Keith *Ib.* 334, note 1.
43. *Ibid*, iv. 4.2. Keith *Ib.* 340. note 4.
44. *Ibid*, iv. 4.3. Keith *Ibid*, 341, note 3.
45. *Ibid.*
46. *Ibid*, v. 3.7. See, Keith *Ib.* 425, note 1.
47. *Ibid*, iv. 4.5. Keith *Ibid* 346, note 1.
48. *Ibid*, v. 3.11, Keith *Ibid*, 347 note 1.
49. *Ibid*, v. 3.10. Keith *Ibid*, 426 note 3.
50. *Ibid*, v. 3.5. Keith *Ibid*, p. 423. n. 2.
51. *Ibid.*

visvajyotis	or	'representing fire, wind and sun' bricks.[52]
rtavya	or	'related to seasons' bricks.[53]
vihavya	or	'invoked, invited or desired' bricks.[54]
apasya	or	'watering' bricks.[55]
dravinoda	or	'granting wealth' bricks.[56]
ayusya	or	'conducive to long life' bricks.[57]
vamabhrt	or	'supporting the desirable as gold, horses etc.' bricks.[58]
adhipatni	or	'female sovereign' bricks.[59]
ajyani	or	'free from injury' bricks.[60]
metre-bricks, like *gayatri, trsthubh, jagati* etc. bricks.[61]		
naksatra-bricks	or	'asterisms like *Krttika, Visakha*, etc bricks.[62]
durva	or	*durva*-grass bricks.[63]
ghee	or	'melted butter' brick.[64]
etc. etc.		

Let us, however, try to be clear about one point. Being a ritual text after all, the *Taittiriya-samhita* is interested in naming the bricks with an exclusive interest in their ritual functions rather than their shape, size, construction, etc. What it seems to be referring nevertheless is to real bricks, sometimes specifying their number and even the manner of placing these.

Thus, for example, *ghee* or 'melted butter'-brick is not intended to mean 'brick made of melted butter', no more than

52. *Tait. Sam.* v. 3.9 See Keith. VBYS 426. n 2.
53. *Ibid*, v. 3.1. Keith *Ibid*. 418 n. 1
54. *Ibid* iv. 7.14. Keith *Ibid*. 386 n. 4. & 438.
55. *Ibid*, v. 2.10. Keith *Ibid*, 414, n. 1 ; 418. n. 1.
56. *Ibid*, v. 3.11. Keith *Ibid*, 427 note 1.
57. *Ibid*.
58. *Tait Sam*. v. 5.3. See Keith. VBYS 442.
59. *Ibid* v. 4.2 Keith *Ibid* 429. note 2.
60. *Ibid*, v. 7.2. Keith *Ibid*, 468. note 2.
61. *Ibid*, iv. 4.4. Keith *Ibid*, 342. n. 8.
62. *Ibid*, iv. 4.10. Keith *Ibid*, 349. note 1 etc
63. *Ibid*, v. 2. 8. Keith *Ibid*, 412.
64. *Ibid*, v. 3.10. Keith *Ibid*, 426 n. 3.

'water'-brick (v.2.10) is intended to mean 'brick made of water' or '*durva*-grass-bricks to mean bricks made of *durva-grass*. What seems to be referred to are real bricks—perhaps even baked ones. But the text is not interested in such physical aspects of the bricks, which appears to have been taken for granted. As a manual of the Vedic priests, it is simply interested in their magical potency and the apparently quaint names of the bricks hinge on this. Here is a passage from the *Taittiriya Samhita*[65] which, however tiring it may appear to the modern readers, is likely to illustrate the point :

He puts down the metre bricks ; the metres are cattle ; verily he wins cattle ; the good thing of the gods, cattle, are the metres ; verily he wins the good thing, cattle. Yajnasena Caitriyayana taught this layer ; by this he won cattle ; in that he puts it down, he wins cattle. He puts down the Gayatris on the east ; the Gayatri is brilliance ; verily at the beginning he places brilliance ; they contain the word 'head' ; verily he makes him the head of his equals. He puts down the Tristubhs ; the Tristubh is power ; verily he places power in the middle. He puts down the Jagatis ; cattle are connected with the Jagati ; verily he wins cattle. He puts down the Anustubhs ; the Anustubh is breath ; (verily it serves) to let the breaths out. Brhatis, Usnihs, Panktis, Aksarapanktis, these various metres he puts down ; cattle verily he wins various cattle ; variety is seen in his house for whom these are put down, and who knows them thus. He puts down an Atichandas ; all the metres are the Atichandas ; verily he piles it with all the metres. The Atichandas is the highest of the metres ; in that he puts down an Atichandas, he makes him the highest of his eqauls. He puts down two-footed (bricks) ; the sacrificer has two feet ; (verily they serve) for support.

For all the gods is the fire piled up ; if he were not to put (them) down in unison, the gods would divert his fire ; in that he puts (them) down in unison, verily he piles them in unison with himself ; he is not deprived of his fire ; moreover, just as man is held together by his sinews, so is the fire held together by these (bricks). By the fire the gods went to the world of heaven ; they became yonder Krttikas ; he for whom these are put down goes to the world of heaven, attains brilliance, and becomes a resplendent thing. He puts down the circular bricks ; the circular bricks are these worlds ; the citadels of the gods are these worlds ; verily he enters the citadels of the gods ; he is not ruined who has piled up the fire. He puts down the all-light (bricks) ; verily by them he makes these worlds full of light ; verily also they support the breaths of the sacrificer ;

65. *Ibid* v. 3 8-10. See, Keith *Ib*. 426-27.

they are the detities of heaven verily grasping them he goes the world of heaven. He puts down the rain-winning (bricks) ; verily he wins the rain. If he were to put (them) down in one place, it would rain for one season ; he puts down after carrying them round in order ; therefore it rains all the seasons. Thou art the bringer of the east wind, he says ; that is the form of rain ; verily by its form he wins rain. With the Samyanis the gods went (sam ayus) to these worlds ; that is why the Samyanis have their name ; in that he puts down the Samyanis, just as one goes in the waters with a ship so the sacrificer with them goes to these worlds. The Samyanis are the ship of the fire ; in that he puts down the Samyanis, verily he puts down a boat for the fire ; moreover, when these have been put down, if the waters strive to drag away his fire, verily it remains unmoved. He puts down the Aditya bricks ; it is the Adityas who repel from prosperity him who being fit for prosperity does not obtain prosperity ; verily the Adityas make him attain prosperity. It is yonder Aditya who takes away the brilliance of him who having piled up a fire does not display splendour ; in that he puts down the Aditya bricks, yonder sun confers radiance upon him ; just as yonder sun is radiant, so he is radiant among men. He puts down ghee bricks ; the ghee is the home dear to Agni ; verily he unites him with his dear home, and also with brilliance. He places (them) after carrying (them) round ; verily he confers upon him brilliance not to be removed. Prajapati piled up the fire, he lost his glory, he saw these bestowers of glory, he put them down ; verily with them he conferred glory upon himself ; five he puts down ; man is fivefold ; verily he confers glory on the whole extent of man.

From the standpoint of the Sulva texts, this is an example of the priestly dictation—of "what is to be done"—wrapped up in all sorts of magical beliefs. For the *Sulva-sutra*-s, however, the question of overriding importance is "How is this to be done?" For answering this question what is important above all is the physical descriptions of the bricks. It is, therefore, natural for the Sulva texts to relegate magico-religious brick-names to the province of the "others", perhaps with due reverence. But the point is that the whole host of magico-religious brick-names proved absolutely useless for the craftsmen and technicians engaged in the work of physically constructing the brick-structure. In the Sulva-texts, therefore, we come across a new set of terminologies referring to the bricks, notwithstanding the rather desultory remains of a few magico-religious brick-names having no specific function for the real construction purpose. The overriding interest of the brick-names in the *Sulva-sutra*-s is mathematical.

But before we pass on to the bricks in the *Sulva-sutra*-s we may have a brief note on the bricks in the *Satapatha Brahmana* which we are required by the Vedic scholarship to accept as text intervening between the *Yajurveda* and the *Kalpa-sutra*-s.

13. BRICKS IN THE SATAPATHA BRAHMANA

It would be wrong, of course, to overlook or ignore the basic fact that the *Satapatha Brahmana,* too, is essentially a ritual text and is hence obliged to remain within the general framework of the system of magico-religious beliefs of the Vedic priests. It is nevertheless interesting to see how we have in it occasional glimpses of a somewhat different understanding of the bricks—an understanding in which bricks are accepted as genuinely physical entities rather than mere words carrying the baggage of magico-religious beliefs.

In the *Satapatha Brahmana*[66] we come across some attempt to explain the etymology of both *citi* (the fire altar) and *istaka* (brick). Thus :

> Now it was those five bodily parts (*tanu*) of his (Prajapati's) that became relaxed,—hair, skin, flesh, bone, and marrow,—they are those five layers (of the fire-altar) ; and when he builds up the five layers, thereby he builds him up by these bodily parts ; and inasmuch as he builds up (*ci*), therefore they are layers (*citi*).

The whole thing is wrapped up in a myth no doubt. Nevertheless we can have in it the glimpse of a five-layered altar actually or physically constructed and the suggested etymology of *citi* from *ci* or the actual work of building up or physical construction cannot perhaps be easily dismissed. Unfortunately, it is not so in the case of the etymology suggested for *istaka*[67] :

> In the fire the gods healed him (Prajapati) by means of oblations ; and whatever oblation they offered that became a baked brick and passed into him. And beecause they were produced from what was offered (*ista*), therefore they are bricks (*istaka*). And hence they bake the bricks by means of fire, for it is oblations they thus make.
>
> He spoke, 'Even as much as ye offer, even so much is my happiness' ; and inasmuch as for him there was happiness (*ka*) in what was offered (*ista*), therefore also they are bricks.

66. *Sat. Br.* vi. 1.2. 17 See Eggeling SBE XLI. 152.
67. *Ibid* vi. 1.2. 22-33. Eggelling SBE XLI. 153.

This etymology of *istaka* is often considered fanciful by the modern scholars and it is bound to be so if it is non-Vedic in origin. But not so are the bricks and the mention of firing them. What is referred to are physical bricks, physically baked, notwithstanding the general framework of the priestly myth within which these are mentioned.

The text also mentions the real or physical materials which the bricks are made of: "the bricks consist of clay and water",[68] "he makes bricks from clay".[69] Sometimes the size of the bricks and the way of arranging these are also specified, though with a thin line of pseudo-logic intended to rationalise the discourse. Thus[70]:

> Now, then, of the measures of the bricks. In the first and last layers let him lay down (bricks) of a foot (square), for the foot is the support; and the hand is the same as the foot. The largest (bricks) should be of the measure of the thigh-bone, for there is no bone larger than the thigh-bone. Three layers should have (their bricks) marked with three lines, for threefold are the worlds; and two (layers may consist) of (bricks) marked with an indefinite number of lines, for these two layers are the flavour, and the flavour is indefinite; but all (the layers) should rather have bricks marked with three lines, for threefold are all the worlds.

In such passages of the *Satapatha Brahmana* we seem to have a faint glimpse of real technologists though as required by the general nature of the text the techniques are referred to as wrapped up with mysticism and magic. Besides, it must not be forgotten that a very large number of the earlier magico-religious—and, therefore, irrelevant from the technological viewpoint—brick-names survive in the *Satapatha Brahmana*, recataloguing of which may prove tedious to the modern readers

14. BRICKS IN THE SULVA SUTRA-S: GENERAL OBSERVATIONS

With the *Sulva-sutra*-s we seem to enter into a new world altogehter. It is the world of the craftsmen or technologists—mainly brick-makers and brick-layers—keenly conscious of the need of precise calculations. A bare list of the varieties of

68. *Ibid* vi. 1.2. 34; vi. 2.1.8.
69. *Ibid* vi. 5.3.7.
70. *Ibid* viii. 7.2.17.

bricks required to construct structures of various shapes may be enough to see this point. We shall give this list mainly from the *Baudhayana Sulva-sutra*. For the calculations in this list the text follows the table of linear measures with which it opens. We have already quoted this table in Section 5 of the present chapter, to which it will be necessary for us to refer constantly.

But let us begin with a number of preliminary observations on the bricks in the *Baudhayana Sulva-sutra*, which gives us almost an impression of fastidiousness of the technicians we meet in the text[71] :

No brick, which has been formed by breaking is to be employed for the constructions of the *agni*. (i.e. a triangular brick which has been formed by dividing a square-shaped brick is forbidden).

No brick, which is cleft (for example, square-shaped brick made out of two triangular bricks) is to be employed.

And no brick which is damaged in any way.

And no brick of black colour (which may be produced by the burning, etc.).

And no brick is to be employed which has some mark (an impression of some foreign body, etc.).

With these points in mind, let us next have a few clarifications about the more complicated brick-structures called Kamya-agni-s or fire altars needed for sacrificial rituals supposed to ensure for their financiers the fulfilment of certain specific desires :

1. The total area to be covered by such a brick structure must be 7½ square *purusa*-s. Let us try to see what it means according to our modern system of measurement. One *purusa* = 120 *angula*-s, and, according to V. B. Mainkar's estimate, one *angula* = 17.78 mm. Thus one *purusa* = 120×17.78 mm. = 2133.6 mm. One square *purusa* = 2.1336×2.1336 meters = 4.552 square meters. Seven and half square *purusa* = 4.552×7.5 =34.14 square meters, or 367.48 square feet. This, in short, means that the total area to be covered by such a brick structure is not negligible even in modern standard.

2. Each structure must be made of five layers of bricks, though the total height of the structure is to be one *janu* or the knee. This gives us some idea of the average height of

71. *Baudh. Sulva-sutra* ii. 52-56. Tr. Thibaut.

the bricks. As the *Baudhayana Sulva-sutra* says, " The fifth part of *janu* is to be taken as the height of the bricks so that the height of the whole *citi* with its five *prastara*-s (layers) is equal to one *janu*".[72] In other words, one *janu* being equal to 32 *angula-s*, the height of each brick is to be $6^2/_5$ or 6.4 *angula* or 113.792 mm. 4.48 inches, or roughly say $4\frac{1}{2}$ inches. But provision had also to be made for making some thinner bricks to meet the requirements of some special type of structure. As the *Baudhayana Sulva-sutra* adds : "The height of the *nakasat*-s and *pancacoda*-s is to be made with half that measure (of height)".[73] Such bricks, thus, are to have the height of $3^1/_5$ *anugla*-s, or, according to our modern measurement, 56.89 mm.

3. The number of bricks to be used for each layer is specified as 200. The total number of bricks for each structure is thus 1000. Lest, however, this number is disturbed, in the special cases in which the thinner bricks are technologically required, it is added "If the intention is to give all the *prastara*-s (or layers) two hundred bricks, then the *pancacoda*-s and *nakasat*-s are to be considered as forming one number together".[74]

4. While arranging the bricks in different layers, the cleft or meeting of the edges of the bricks used in the lower and its immediately upper layer is to be avoided. Such clefts are technically called the *bheda*-s. As Thibaut explains, "Every *agni* consists of five layers (*prastara-citi*) of *bricks* (200 bricks in each layer). Now the bricks in the second layer, for instance, had to be arranged in that way that none of them ever covered exactly a brick of the first layer, but that the line in which two bricks of the first layer were meeting was covered by a brick of the second layer. The same rule had to be observed with regard to the second and third layers, and so on".[75] The importance of this rule from the technological view-point is obvious, for without observing this the structure as a whole would not have any stability and would

72. *Ibid.* ii. 58.
73. *Ibid.* ii. 59.
74. *Ibid.* ii. 28.
75. Thibaut on *Baud Sul. Su.* ii. 23.

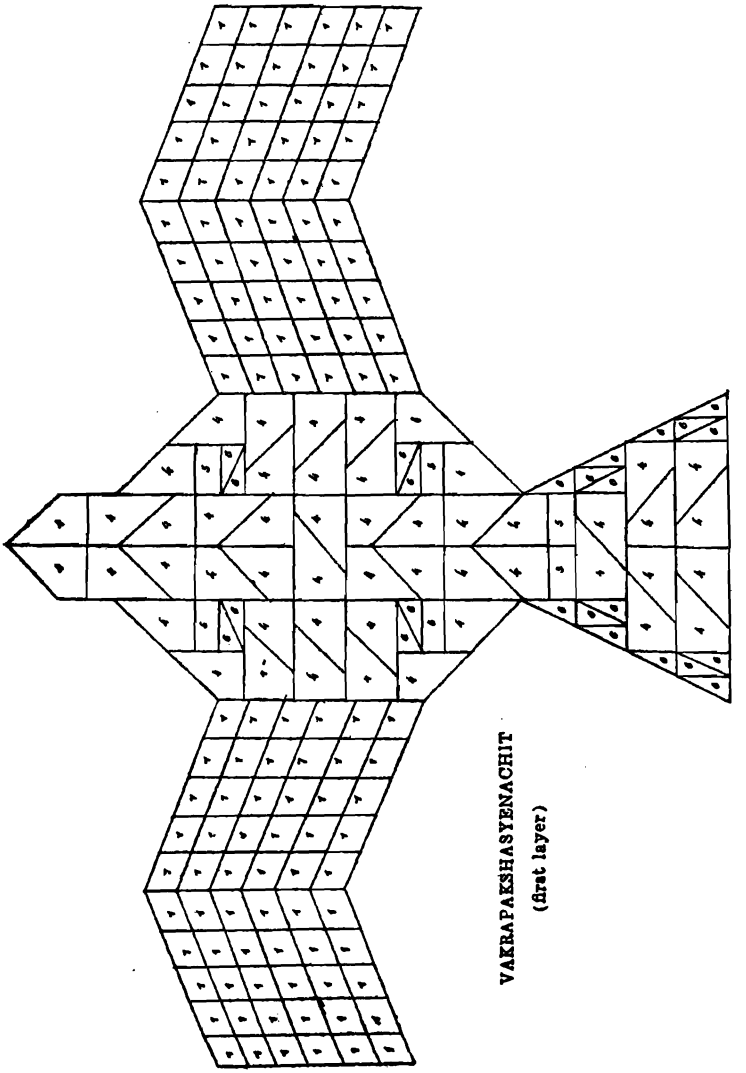
crumble down, specially when there was no provision for the use of mortar for joining the bricks. Interestingly, however, the brick-layers in the Sulva texts also knew that to maintain the exact size and shape of the brick-structures they were required to execute, this rule of avoiding the *bheda*-s could not be adhered to too rigidly, or that there were cases when exceptions had to be made to it. As the *Baudhayana Sulva-sutra* puts the point: "These *bheda*-s do not occur (are not to be considered as such) on the outer periphery of those *agni*-s (for there of course the edges of the bricks of all five layers must meet). And secondly not (i.e. the rule is not valid) in the case of the angles and of the sides. (This refers to the *sararatha-cakra-citi,* where unavoidable *bheda*-s occur in the centre of the *nabhi*—the nave of the wheel and on the side of the *ara*-s, the spokes)".[75]

5. In the text itself, the need is naturally felt for giving separate lists of brick-types for the construction of structures with different shapes. Evidently, the kind of bricks required for the construction of a structure having the shape of a falcon with stretched wings are not suitable for the purpose of constructing a structure having the shape of a chariot wheel with or without the spokes. Even for the same structure like the falcon-shaped one, bricks of different sizes and shapes are required. So it is no use to look for any standardised brick-type in the Sulva texts. The technicians in our text had to improvise a large number of brick-types to execute what they were asked to do. What amazes us even today is the mathematical precision they maintained for the purpose and the way in which they mentioned the names of the brick-types almost invariably using mathematical terms to indicate their shapes and sizes.

15. BRICK-TYPES: SOME EXAMPLES

With these general points in mind, let us try to have some idea of the technological-mathematical questions discussed in the Sulva texts concerning the brick structures called *agni* or *citi* in the priestly terminology. It will not be within the scope of our present discussion to review all the brick-types for the

76. *Baudh. Sul. Su.* ii. 24-25.



VAKRAPAKSHASYENACHIT
(first layer)

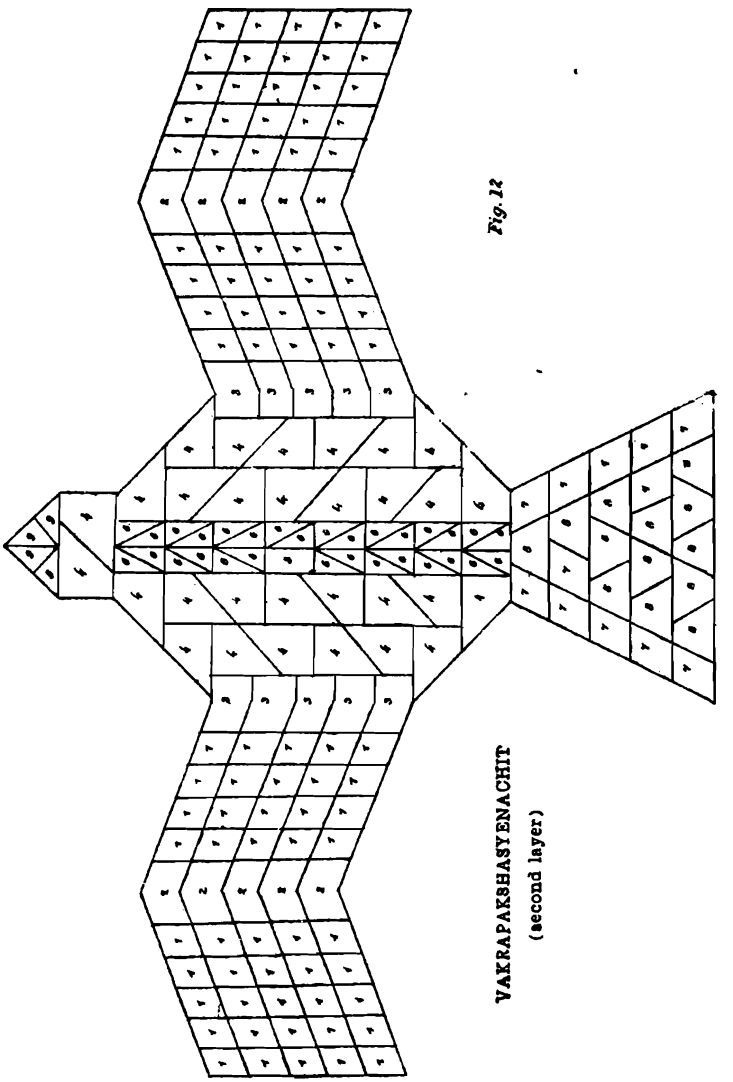


Fig. 12

VAKRAPAKSHASYENACHIT
(second layer)

making of the different structures discussed in the texts. Nor is it necessary for our purpose, because competent scholars like Thibaut and others have already done it. Our purpose being only to show that the mathematics in the Sulva texts is actually rooted in—or emerges from—brick technology rather than the priest-craft dictating the terms for the construction of such brick structures, it may be sufficient for our purpose to have some general idea of one of such structures. We propose to concentrate here on the brick-structure which, in the priestly nomenclature, is called the Vakrapaksa-syena-citi, which means a brick-structure having the shape of a falcon with outstretched and bent wings. "The *Vakrapaksa-syena* itself could be constructed in different forms. Two forms are described by Baudhayana, two by Apastamba".[77] It may be recalled here that according to the general requirement of avoiding clefts or *bheda*-s, the arrangement of bricks in the first, third and fifth layer of the structure has to be different from that of the second and fourth layer, two different patterns of brick arrangement are suggested for each such layers of this structure. We reproduce here Thibaut's diagrams of the two layers of brick arrangement for the two kinds of Vakrapaksa-syena-citi based on *Baudhayana Sulva-sutra*. It is evident from these diagrams that such a brick-structure cannot be constructed only with one type of bricks. So one of the essential problems here is that of the kind of bricks required for the construction. As an example of how this problem is solved in the texts, we give here from the *Baudhayana Sulva-sutra* the list of ten varieties of bricks required for the construction. It needs to be noted that the text specifies the shape and size of each variety of bricks, from which it should be immediately obvious how sophisticated is the brick technology presupposed by the text and how much of mathematical calculation is required for the purpose. Significantly, each brick-type is given its specific name and each name is a pointer to the mathematical mind working behind it, evidently in the interest of precision.

Following is the list of ten types of bricks required for the construction of the structure called Vakrapaksa-syena of the second variety according to *Baudhayana Sulva-sutra*.

77. Thibaut in *SHSI*, II 449.

1. *Pancami*, Literally one-fifth. These are square shaped bricks, the side of which is one-fifth of a *purusa*, i.e. 24 *angula*-s. In other words, these square shaped bricks have the measure of 24×24 *angula*-s or 576 square *angula*-s. Lest there be any vagueness about the exact size of such bricks, Thibaut explains that had it been possible to cover the entire area of 7½ square *purusa*-s only with such bricks, the total number of bricks required would have been 187½ for each layer, "One square *purusa* contains 25 such bricks, therefore 7½ square *purusa*-s = 187½ *pancami*-s".[78] The calculation is quite simple: Each brick = 24×24 *angula*-s = 576 square *angula*-s; 25 such bricks, 576×25 = 14,400 square *angula*-s or one square *purusa*; 576×187.5 = 108,000 square *angula*-s = 7½ square *purusa*-s. However, it is specified that each layer is to consist of only 200 bricks, which means that the construction of the altar is more than the question of stacking only a certain number of the *pancami* bricks. Bearing this in mind it is easy to judge that a brick structure as complicated as to have the shape of a falcon with out-stretched and bent wings cannot be constructed with such square bricks alone: various other types of bricks with various shapes and sizes are evidently needed for the purpose, i.e. over and above a certain number of these square bricks. Hence our text passes on to mention bricks of other types required for the purpose.

2. *Adhyardha*, Literally longer by half. Since this is mentioned in the immediate context of the *pancami* bricks, we may—for our purpose—assume that the expression presupposes *pancami* and hence we have to understand these as (*pancami*)-*adhyardha*. The *Baudhayana Sulva-sutra* describes the first two forms of bricks as "Bricks the side of which (i.e. one side of which) is equal to the fifth part of a *purusa* (i.e. half of the side of the *pancami* (24 *angula*-s) and bricks which are longer on one side by a half (i.e. longer by half of the side of the *pancami* (i.e. 24+12=36 *angula*-s)"[79]. In simpler language, it means this second type is oblong-shaped bricks the size of which is 24 *angula*-s×36 *angula*-s or 864 square *angula*-s in area.

78. Thibaut on *Baudh. Sul. Su.* iii. 106.
79. *Baudh. Sul. Su.* iii. 118.

3. *Sapada,* literally with an extra one-fourth. Occurring, again, as it does in the immediate context of the *pancami*, we can perhaps use for it the expression (*pancami-*) *sapada*. This means oblong bricks one side of which is equal to that of the *pancami* (i.e. 24 *angula*-s) and the other one-fourth more than this (i.e. 24 *angula*-s + 6 *angula*-s = 30 *angula*-s). In short, these are rectangular bricks measuring 24 *angula*-s × 30 *angula*-s, or 720 square *angula*-s.

4. *Ardhya,* literally measuring half. In the immediate context of *pancami,* we can perhaps use for it the expression (*pancami-*) *ardhya.* It needs to be remembered here that the *Baudhayana Sulva-sutra* had already instructed that in the context of bricks, the process of having a square or rectangle is to be understood as by drawing a diagonal on it. As the text puts it, "(If there are mentioned half-bricks, quarter-bricks, etc.), the division (of the original brick) is always to be made following the diagonals in case there is no special direction given".[80] Accordingly, half of *pancami* brick mentioned here refers to the isosceles right-angled triangle obtained by drawing a diagonal on the *pancami* brick. *Pancami* brick being 24×24 *angula*-s, the triangular brick referred to here as *ardhya* shall have the three sides as 24 *angula*-s by 24 *angula*-s by 33.94 [i.e. $\sqrt{(576+576)} = \sqrt{1152} = 33.941$ *angula*-s]. Its area = half of 576 = 288 sq. *angula*-s.

5. *Padya,* literally measuring a quarter. In the general context of the *pancami*-s, these bricks are to be understood as (*pancami-*) *padya*-s or quarters of *pancami*-s. Following the general rule already quoted, viz. that expressions like half-bricks and quarter-bricks are to be usually measured by drawing diagonals on the rectangular or square bricks under consideration, by the *padya*-s are to be understood here as triangular bricks the size of which is to be obtained by drawing two diagonals on a *pancami* brick—the size of each *pancami* brick thus giving four equal triangular bricks. A *pancami* brick having the size of 24×24 *angula*-s, the size of each *padya* brick is equal to 24 *angula*-s by 16.97 *angula*-s by 16.97 *angula*-s. Its area being one-fourth of 576 = 144sq. *angula*-s.

80. *Ibid.* iii. 65.

6, 7 and 8. The next three brick sizes are cryptically referred to by our text as *tatha adhyardhayah*. Thibaut translates it as "In the same way (bricks are made which are equal to the half and fourth part) of an *adhyardha* brick."[81]. In other words, just as the *ardhya* and *padya* bricks referred to are made by diagonally dissecting the *pancami* bricks, so also by diagonally dissecting an *adhyardha* brick, we get new types of triangular bricks. But the *adhyardha* being oblong in shape, the similar process of diagonally dissecting it yields altogether three—instead of two—triangular shaped bricks which, in the Sulva terminology, are *ardha adhyardha*, *dirgha-adhyardha* and *sula-padya*. Thus :

6. *Ardha-adhyardha*. The *adhyardha* brick being oblong having its two sides as 24 and 36 *angula*-s, the simple division of it into two by drawing a diagonal gives us two triangular bricks, the sides of each of which are 24, 36, 43.266 *angula*-s. Its area = ½ of 864 = 432 sq. *angula*-s.

However, dividing the same oblong brick into four by drawing two diagonals on it, we get two types of equal traingular bricks. As Thibaut explains, "As the *adhyardha*-brick is not a square, but an oblong, it is divided by its two diagonals into four triangles of which two and two are equal to each other. The technical names of these two different kinds of triangular bricks are *dirghapadya* and *sulapadya*".[82] Incidentally these two names do not occur in the text itself and are found in the commentaries. However, for our purposes, the point to be noted is that by cross-division of the oblong of 36×24 *angula*-s by two diagonals, we get two pairs of bricks —each in the pair having the same measure. These are :

7. Dirgha-padya=the sides of which are 36, 21.63, 21.63 *angula*-s.

8. Sula-padya=the sides of which are 24, 21.63, 21.63 *angula*-s.

Area of each Dirgha-padya brick=216 sq. *angula*-s
Area of each Sula-padya brick=216 sq. *angula*-s.

9. *Ubhayi*, literally made of parts of both. The text describes it as follows : "The eighth part of a *pancami* and of

81. *Ibid* iii. 121.
82. Thibaut on *Baudh. Sul. Su.* iii. 121.

an *adhyardha* have to be combined in that manner that three corners (i.e. a triangle) are the result"[83]. Thibaut explains : "For this purpose the *padya* of a *pancami* is divided by a line drawn from the apex to the middle of the base ; the result is a rectangular triangle the sides of which are 12 *angula*-s, 12 *angula*-s and 16 *angula*-s 33 *tila*-s. This is the eighth part of the *pancami*. In the same way, the *dirghapadya* of an *adhyardha*-brick is divided, the result is the nominally eighth part of the *adhyardha*—a rectangular triangle the sides of which are 12 *angula*-s, 18 *angula*-s and 21 *angula*-s 21 *tila*-s. By putting together the equal sides of these two triangles, we get a scalene triangle the sides of which=16 *angula*-s 33 *tila*-s, 21 *angula*-s 21 *tila*-s and 30 *angula*-s. The name of a brick of this kind is *ubhayi*". (Its area = 180 sq. *angula*-s).[84]

10. *Astami*, literally one-eighth ; "And bricks which are equal to the eighth part of a *pancami*".[85] Following the general principle of dividing by drawing diagonals, we get four triangular parts of a *pancami* brick and then by drawing a line from the vertex to the middle of the base of each of these four triangles, we get altogether eight triangular bricks, each of which will be one-eighth of a *pancami* brick in areas, The three sides of each of such eight bricks will be 12 *angula*-s, 12 *angula*-s and 16.97 *angula*-s. Its area $=1/8 \times 576 = 72$ sq. *angula*-s. Such then, are the ten varieties of bricks required for making the structure called *vakrapaksa syenaciti* of the second type. As the *Baudhayana Sulva-sutra* sums up : *iti dasa*—"These are altogether ten different classes of bricks".[86]

Before passing on to survey the technique of laying such varieties of bricks discussed by our text for the construction of the structure covering the total area of 7½ square *purusa*-s resembling a falcon with stretched and bent wings and made of five layers each with 200 bricks in such a manner that the joint of two bricks in one layer does not overlap the joining of bricks in the layer immediately above it, we may as well note another point. The ten varieties of bricks just enumerated are required only for the construction of one type

83. *Baudh. Sul. Su.* iii. 122.
84. Thibaut on *Baudh. Sul. Su.* iii. 122.
85. *Baudha. Sul. Su.* iii. 123.
86. *Ibid.* iii. 124.

of structure. To the technologists and mathematicians of the Sulva texts, however, came down the problem of constructing not only this type of structure. They were required to construct various types of structures besides. Understandably the need was felt also for other types of bricks for the construction of structures of other shapes. In the Sulva texts, accordingly, we come across specifications of bricks of various other shapes and sizes, all bearing technological-mathematical names. We may have some idea of this from the following list, though for the sake of simplicity we give here only the shapes and sizes of some of these bricks, without their technical names :

1. Square bricks, the side of which is one-fourth of a *purusa i.e.* 30×30 *angula*-s.
2. Square bricks the side of which is one-sixth of a *purusa,* i.e. 20×20 *angula*-s.
3. Square bricks the side of which is one-tenth of a *purusa,* i.e. 12×12 *angula*-s.
4. Oblong bricks of 24×12 *angula*-s in size.
5. Oblong bricks of 20×10 *angula*-s in size.
6. Triangular bricks sides of which are 30, 30, 42.42 *angula*-s.
7. Triangular bricks obtained by dividing a 30×30 *angula*-s square brick into four parts by drawing two diagonals on it ; i.e. each of the four such triangular bricks has for its three sides : 30 *angula*-s, 21.21 *angula*-s and 21.21 *angula*-s.
8. Bricks of the shape of a trapezium obtained by adding an oblong of the size 15×7½ *angula*-s to a triangle on it having the three sides as 15 *angula*-s, 15 *angula*-s and 21.21 *angula*-s.
9. Bricks of the shape of an irregular pentagon—the sides of which are 30 *angula*-s, 7.5 *angula*-s 21.21 *angula*-s, 21.21 *angula*-s and 7.5 *angula*-s—with the total area of 450 square *angula*-s (i.e. half of the area of 30×30 *angula*-s). The name given to the type of brick is "swan-beaked" or Hamsamukhi.
10. Trapezium-shaped bricks with sides measuring 6, 12, 18 and 16.97 *angula*-s.
11. Trapezium-shaped bricks with sides measuring 24, 24, 48, 33.94 *angula*-s.

12. Rectangular bricks measuring 38 *angula*-s 25 *tila*-s by 19 *angula*-s 12½ *tila*-s.
13. Triangular bricks the measurement of which is obtained by diagonally bisecting the above rectangular bricks.
14. Triangular bricks the measurement of which is obtained by quartering the above (i.e. No. 12) rectangular bricks with two diagonals and having for its base the longer side.
15. Triangular bricks the measurement of which is obtained by quartering the above (No. 12) rectangular bricks with two diagonals and having for its base the shorter side.
16. Square bricks with an area of one-thirtieth of a square *purusa*, i.e. square bricks with an area of 480 square *angula*-s, or 21.9×21.9 *angula*-s

The list may indeed be made much longer. But that is not necessary for our purpose. Readers interested in a more exhaustive list of the brick types mentioned in the Sulva texts, may profitably look up *The Sulbasutras* by Sen and Bag. For the purpose of our own discussion, two points are specially to be noted in this connection.

First, the impression of brick technology we have from the Sulva texts is, to say the least, extremely sophisticated. Evidently enough, it presupposes a class of highly skilled craftsmen whom it may not be an error to consider as whole-time specialists or at least those that had inherited the tradition of generations of specialists. Judging from the minute details of ritual prescriptions recorded in the *Yajurveda* and *Brahmana*-s, the Vedic priest-craft, too, cannot but presuppose similar whole-time specialists, though devoted to matters other than technology in its real sense. This suggests that the class of brick-technologists and Vedic priests could hardly belong to the same class of people. If, in spite of this, it is argued that a section of Vedic priests chose to specialise in brick-technology, it would be necessary to admit that they did it not in the strict capacity of Vedic priests but somehow deviating from their priest-craft.

Secondly, the brick-types mentioned in the Sulva texts are, from the very nomenclature used for these, unmistakable pointers to technological-mathematical temper caring above all for the accuracy of measurement, which, in its turn, evi-

dently presupposes precision of observation. Such a theoretical temper is totally wanting in—and, as a matter of fact, even contrary to—not merely in the general trend of thought we find in the *Yajurveda* and the *Brahmana* texts but also in the very nomenclature of the brick-types in the priestly literature in its strict sense. Thus the mere fact that the *Sulva-sutra*-s come down to us as appended to the priestly literature cannot be viewed as a decisive evidence for the Vedic priests themselves having been the makers of mathematics as codified in the Sulva texts.

16. MASONRY AND ARCHITECTURE

Equipped with such a wide variety of brick-types the masons and architects in the *Sulva-sutra*-s proceed to the physical construction of the brick-structures, showing again their basic interest in mathematical questions combined with superb craftmanship—or, perhaps as better expressed, in the mathematical questions arising out of the requirements of their craftsmanship. Thanks to the pioneering work of Thibaut and others, it is not necessary for us to try to re-explore the details of this aspect of the Sulva texts. Depending on the critical evaluation of the major commentaries on the texts, they have analysed the cryptic aphorisms and reconstructed from these with excellent diagrams the technique followed for the physical construction of the different brick-structures with different names. For our own purpose of meeting the masons and architects in the *Sulva-sutra*-s, it may be enough to follow Thibaut, though readers interested in more details may profitably consult also the recent work by Sen and Bag.

Our present purpose being to have some idea of how the Sulva mathematics is inextricably related to the work of the masons and architects, we are not required to discuss here the construction of all the brick-structures. It may be adequate, instead, to follow Thibaut's review of the technique followed for the construction of the comparatively complicated brick-structure, the *Vakrapaksa-syena-citi*—a brick-structure having the shape of a falcon with outstretched and bent wings. The Sulva texts discuss the construction of different forms of such a brick-structure, of which we shall quote here what is said about the two types.

We have seen the diagrams of the two different layers of the brick-arrangements of the first kind of Vakrapaksa-syena brick-structure prepared by Thibaut on the basis of the *Apastamba Sulva-sutra*. Explaining these Thibaut[87] observes :

The following extract contains Apastamba's rules for the first kind of the *Vakrapaksa-syena* :

'He who wishes for heaven, may construct the altar shaped like a falcon ; this is the tradition.

'His wings are bent and his tail spread out.

'On the west side the wings are to be drawn towards the east, on the east side towards the west.

'For such is the curvature of the wings in the middle of the birds, says the tradition.

'Of the whole area covered by the seven fold *agni* with *aratni* and *pradesa*, take the *pradesa*, the fourth part of the *atman* (body without head, wings, and tail) and 8 quarter bricks ; of these latter, 6 form the head of the falcon ; the remainder is to be divided between the two wings'.

The *sutra* determines what portions of the legitimate area of the *agni* have to be allotted to the different parts of the falcon construction. The whole area of the *saptavidha agni* is seven *purusa*-s with the addition of the two *aratni*-s on the wings and the *pradesa* of the tail, altogether $7\frac{1}{4}$ *purusa*-s. Now the fourth part of the atman (of the primitive *syena-citi*) one *purusa* and the *pradesa*, i.e., an oblong of 120 *anguli*-s by 12 *anguli*-s $= {}^{1}/_{10}$ square *purusa* and eight quarter bricks, (i.e., square bricks the side of which is equal to the fourth part of a *purusa* = 30 angulis, so that they cover together an area of $^{1}/_{2}$ square *purusa*) are given to the wings in addition to the area which they cover in the primitive *agni*, only they have to cede in their turn three of the eight quarter bricks, which are employed for the formation of the head. The original area of both wings together being $2^{2}/_{5}$ *purusa*-s, their increased area amounts to $2^{2}/_{5} + 1^{3}/_{5} - {}^{3}/_{16} = 3^{13}/_{16}$ square *purusa*-s, for one wing to $^{129}/_{32}$ square *purusa*-s.

"Nine and half *aratni*-s (=238 *anguli*-s) and three quarters of an *anguli* are the length of the wing.'

The breadth of the wing is the same as in the primitive *syena*, i.e., =1 *purusa* = 120 *anguli*-s. Dividing the area of the wing mentioned above by the breadth we get the length. Up to this, the wing has the shape of a regular oblong ; the following rules show how to produce the curvature :

'Make ties at both ends of a cord of two *purusa*-s length and a mark in its middle.

'Having fastened the two ends of the cord at the two western corners of the oblong forming the wing, take it by the mark and stretch

87. Thibaut in SHSI II. 449-53.

it towards the east; the same is to be done on the eastern side (i.e. the cord is fastened at the two east corners and stretched towards the east). This is the curvature of the wings.'

By stretching the cord, fastened at the west corners, a triangle is formed by the west side of the oblong and the two halves of the cord, and this triangle has to be taken away from the area of the wing. In its stead the triangle formed, when the cord is stretched from the eastern corners, is added to the wing.

'Thereby the northern wing is explained'.

The curvature is brought about in the same way:

'The *atman* is two *purusa*-s long, one and a half *purusa*-s broad'.

This is not the final area of the *atman*, as we shall see further on; but an oblong of the stated dimensions has to be constructed and by cutting pieces from it we get the area we want.

'At the place of the tail, stretch a *purusa* towards the west with the breadth of half a *purusa*'.

That means: construct an oblong, measuring one *purusa* from the east to the west, half a *purusa* from the north to the south.

'To the south and to the north of this oblong, construct two other oblongs like it, and dividing them by their diagonals remove their halves so that half a *purusa* remains as breadth at the jointure of *atman* and tail.

The result is the form of the tail which we see in the diagram.

'At the place of the head a square is to be made with half a *purusa*, and from the middle of its east side cords are to be stretched to the middle of the northern and the southern side.

The triangles cut off by these cords are to be taken away from the area of the head.

'Then the four corners of the *atman* are cut off in the direction towards the joining lines. This finishes the measurement of the *syena*. Its four corners are cut off by four cords connecting the ends of the lines in which the *atman* and the wings touch each other with the ends of the lines in which head and tail are joined to the *atman*'.

17. AN EXAMPLE OF MATHEMATICAL EXCELLENCE

We propose to add only one point to the above.

It is concerning the mathematical excellence implicit in what is just said. This is evident from one special brick-type mentioned for the construction of the structure. As described by the *Apastamba Sulva-sutra*, "One class of bricks has the length of the fifth of a *purusa*, the breadth of a sixth bent in such a way as to fit (the place in which they are to be em-

ployed)".[88] Thus, in other words, these bricks have the size of 24 *angula*-s by 20 *angula*-s. But these are not rectangular bricks, as indicated by the word "bent". What, then, is meant by "bent" here? Thibaut explains: "By *nata*, 'bent', the Sutrakara means to indicate that the sides of the brick do not form right angles. The shape of the brick is of a parallelogram the angles which the sides form with each other, are the same which the wings of the *syena* (falcon) form with the body".[89]

Let us now note the special mathematical interest of the use of this type of bricks.

In the first layer of the brick-structure under consideration, as can be seen from Thibaut's diagram, this type of bricks is used only for the construction of the wings—60 such bricks in each wing, i.e. 120 such bricks in all. The total area to be covered by each wing is 27,450 square *angula*-s, i.e. 54,900 sq. *angula*-s for the two wings together.

Thus, in other words, the total area to be covered by 120 bricks each of which is 24 *angula*-s in length and 20 *angula*-s in breadth is to be 54,900 sq. *angula*-s. Had these bricks been rectangular, the area of each would have been $24 \times 20 = 480$ square *angula*-s, i.e. the total area covered by 120 rectangular bricks would have been 57,600 sq. *angula*-s, instead of the prescribed total area for the two wings being 54,900 square *angula*-s. Hence is the crucial importance of the expression of *nata* or 'bent' in connection with such bricks. It means that the area covered by a parallelogram-shaped brick 24 *angula*-s long and 20 *angula*-s broad is not 480 square *angula*-s but evidently 457.5 sq. *angula*-s. One hundred and twenty such parallelogram-shaped bricks thus cover the total area of 54,900 sq. *angula*-s, which answers to the area prescribed for the two wings together. This, in short, means that the technician-mathematicians of our text *knew the way of calculating the area of a parallelogram the length of the two sides of which are given (in this particular case the actue angle between the two sides of the parallelogram being 72.3875 degrees) and that this area is different from that of a rectangle with the same length and breadth.* For a

88. Quoted by Thibaut, *Ibid.* 453.
89. Thibaut *Ibid.*

mathematician today, the calculation implied in this difference may be somewhat familiar. But to meet in the ancient Sulva texts mathematicians having precise knowledge of this difference—or, more simply, the technique of precise calculation of the area of a parallelogram with given sides as distinguished from a rectangle of the same given sides—is, to say the least, highly remarkable from the historical viewpoint. The step taken by the Sulva mathematicians must have been a prodigious one. From the statement that 120 parallelogram-shaped bricks—the two sides of which are 24 and 20 *angula*-s—should cover the total area of 54,900 square *angula*-s, it can be reasonably thought that they were also aware of the necessary angle in which such bricks were to be "bent", i.e. the fact that the area of a parallelogram depends on the exact angle between two of its adjacent sides or on its altitude. In the present case had the acute angle of the parallelogram been greater or lesser than 72.3875 degrees, the total area to be covered by 120 such bricks too, would have been greater or lesser, or the total number of bricks required would have been different.

18. TERMINOLOGICAL PRECISION

The making of an exact science presupposes the creation of a whole host of terminologies, each to be used in a precise sense. In the names of the brick-types improvised in the Sulva texts we already have some idea of how this was done by the makers of mathematics in ancient India. But terminological precision is not confined in the Sulva texts only to such brick-names. The need was also felt to use precise terminologies specifically in matters mathematical. Old words or words already in circulation were sometimes retained no doubt. However, connotation of these are firmly fixed, generally in the interest of mathematical precision. Only a few examples of this may be enough for the purpose of appreciating the general theoretical climate of the *Sulva-sutra*-s. Here is a list of some such terminologies from the *Baudhayana Sulva-sutra* :

Amsa : Literally, shoulder. Technically, two eastern corners of a square brick-structure I.34.

Aksnya : A technical word introduced in Sulba-sutra in the specific sense of 'diagonally'. Thus, *aksnya-rajju* means a diagonal line, a cord stretched across a square or oblong. I.46.

Prauga : Literally, forepart of the shafts of a chariot. But technically in the specific sense of isosceles triangle. Thus, *ubhayatah-prauga* (lit. having an isosceles triangle on both sides) means a rhombus. I.57.

Rju-lekha : Straight line. II.32

Karani : Literally, an instrument. But technically in the specific sense of a side (of a square). I.55.

Caturasra : Ordinarily, four-cornered. But, technically, a square (= *sama-caturasra*) or rectangle (= dirgha-caturasra). I.22.

Tiryak : Ordinarily, lying crosswise, obliquely, transversely. But, technically, breadth. I.46. Thus, *tiryan-mani* means breadth of shorter side of an oblong. I.38, I.48.

Nyanchana : A mark determined by the following procedure : Make a mark of the western half of the cord less the fourth part (of the half). The name of this mark is *nyanchana* I.32-33.

Tri-karani and Tritiya-karani (I.47) : Thibaut explains : "If seems that, in order to find the *tritiya-karani*, we are directed to find at first the *trikarani ;* the third part of the *tri-karani* is the *tritiya-karani* ; for it is the side of a square the area of which is one-ninth of the square of the *tri-karani* and consequently, one-third of the given square".

Pramana ; Measure. I.3.

Parikarsana : Literally, dragging about. But, technically in the sense of 'circle'. III.210.

Parsvamani : Horizontal side, i.e. longer side of an oblong. I.48.

Viskambha : Literally, a prop, support. But, technically, in the sense of 'diameter'. I.25 & 26.

Savisesa : a ratio : diagonal of a square divided by the side of the same square= $\sqrt{2}=1.414256$. I.62.

Vrdhra

(Vrddha) : A technical term, meaning, cut-off piece. I.50.

19. POLITICAL PHILOSOPHY OF THE SATAPATHA BRAHMANA

From what is so far discussed about the Sulva texts—specially the one associated with the name of Baudhayana—one point is on the surface. It is the importance sought to be attached to accuracy—accuracy of the table of linear measures, in the enunciation of the geometrical propositions required although the technological problems to be confronted for construction of brick-structures of various shapes, in the determination of the shapes and sizes of the different brick-types, in improvising a whole host of technical terms without which exact science is inconceivable. Judged specially in the ancient context, this zeal for accuracy in the Sulva texts cannot but appear to us to be remarkable, even where the texts fail to have exact solutions of some of the problems these are bold enough to confront, e.g., in the case of squaring a circle or circling a square.

What, then, is the basis of this emphasis on accuracy? The quest for theoretical consistency—and sometimes perhaps also deductions though implicit—need not be overlooked. These seem to be specially conspicuous in the case of the geometrical propositions, with the enunciation of which our text opens. Nevertheless, even in these cases we meet the manual workers with their strings and poles, drawing in their own ways the basic geometrical figures and discussing their properties with very strong empirical bias. This is indicative of the actual source of the demand for accuracy of the Sulva texts. What we are trying to emphasise, in other words, is that the zeal for accuracy has its real moorings in actual observation, connected with manual operation. It is this that forms the very basis of the mathematical science in the *Sulva-sutra*-s.

This point is of material significance for what we are trying to argue, because it is an index to the general theoretical temper of the makers of mathematics in ancient India. Before hasitly concluding that they were the Vedic priests, we cannot evade one question: How far this theoretical temper can at all be imputed to these priests? How far, in other words, is it legitimate to assume that the Vedic priests were actually keen on the accuracy of observation with a distinct mooring in manual work? In order not to be arbitrary, we have to seek the answer to the question from the priestly

literature in its strict sense, specially the *Brahmana*-s which are overtly interested in ideological questions. In the special context of our discussion, it may not be a methodological error to concentrate mainly to the internal evidences of the *Satapatha Brahmana*, which, among the *Brahmana*-literature, discusses the question of the fire-altars most elaborately.

What, then, is the theoretical temper—or, more broadly, the characteristic ideology—of the Vedic priests of which we have indications in the *Satapatha Brahmana?* And, how far is it compatible with the zeal for direct observation having a distinct mooring in manual operation?

Before we proceed to seek an answer to these questions, it is necessary to note one point. Though essentially a ritual text, the *Satapatha Brahmana* is very definitely committed to a political position—to the validation of a social norm—and the general theoretical temper of the Vedic priests is inextricably connected with it. In other words, the characteristic ideology of these priests and their theoretical temper are in need of being discussed in the general background of this political commitment.

What, then, is the nature of this political commitment? Our text does not mince words about it. Its essence is to establish the political power and privileges of mainly the Ksatriyas—"the nobility" or "the lordly power"—who, in those days, could be the *yajamana*-s or rich patrons financing the sacrifice, though, along with it, the superiority of the Brahmin priests,—"holy power"—subsisting almost exclusively on the *daksina* or fees for performing the sacrifice.

Let us begin with an account of a controversy about altar-construction we read in the *Satapatha Brahmana.*

While the Sulva texts specify the shape and size of every brick-type and generally give the brick-names in terms of these, the *Satapatha Brahmana,* being a ritual text after all, is naturally interested primarily in their magical efficacy in terms of which the brick-types are frequently named. One such name is *lokam-prna,* usually translated as the "space-filling" ones. It seems that from the view-point of one theological trend, which is associated with the name Tandya, the *lokam-prna* is a "technical term for those bricks which have no special prayers belonging to them, but are piled up with a common formula beginning with *lokam-prna chidram-*

prna, 'fill the space, fill the gap' ".[90] These are supposed to be contrasted with "the *Yajusmati* (prayerful) bricks which bear special names, and have special formulas attached to them".[91] Apparently sharing this view, the theologian Tandya declared :[92]

Surely the bricks possessed of prayers are the nobility, and the space-fillers are the peasants, and the noble is the feeder and the peasantry the food ; and where there is abundant food for the feeder, that realm is indeed prosperous and thrives : let him therefore pile up abundant space-fillers.

But the text refuses to accept it as "the standard practice". Hence it elsewhere declares.[93]

And, again, as to why he lays down a *lokam-prna*—the *lokam-prna*, doubtless is the nobility (or chieftaincy), and these other bricks are the peasants (or clansmen) : he thus places the nobility (or chieftain), as the eater, among the peasantry. He lays down in all the layers : he thus places the nobility, as the eater, among the whole peasantry (or in every clan).

In his notes Eggeling[94] explains the controversy :

At VI. 1. 2.25, Tandya was made to maintain that the Yajusmatis, or bricks laid down with special formula, were the nobility, and that the lokamprnas, laid down with one and the same formula, were the peasants, and as the noble (or chieftain) required a numerous clan for his subsistence, there should be fewer of the former kind of bricks, than the established practice was. This view was however rejected by the author of the *Brahmana*, and here in opposition to that view, the *lokamprna* is identified with the nobility, and the Yajushmatis with the clan.

To the modern readers the controversy over the question whether the *lokam-prna* (space-filling) and *Yajusmati* (prayerful) bricks are to be identified with the peasantry or the nobility may appear to be totally arbitrary. But not the political view on which the representatives of both the theories fully agree. According to it the "noble" is to be made supremely powerful and the peasantry completely subservient, by the magic power of the ritual. This political norm repea-

90. Eggeling, SBE XLI. 153 n.
91. *Ibid.*
92. *Sat. Br.* vi. i. 2.25 Tr. Eggeling.
93. *Ibid.* viii. 7.2.2 Tr. Eggeling.
94. Eggeling SBE. XLIII, 132 n.

tedly occurs in the *Satapatha Brhmana* even in connection with the theme of altar-construction. Thus :[95]

And inasmuch as, in going from here, the horse goes first, therefore the Ksatriya, going first, is followed by the three other castes ; and inasmuch as, in returning from there, the he-goat goes first, therefore, the Brahmin, going first, is followed by the three other castes. And inasmuch as the ass does not go first, either in going from here, or in coming back from there, therefore the Brahmin and Ksatriya never go behind the Vaisya and Sudra : hence they walk thus in order to avoid a confusion between good and bad. And, moreover, he thus encloses those two castes (the Vaisya and Sudra) on both sides by the priesthood and the nobility, and makes them submissive.

Another ritual brick-name in the text is *rtavya* usually rendered as "seasonal bricks". And the text declares :[96]

And, again, as to why he lays down seasonal (bricks), the seasonal (ones) are the nobility and these other bricks are the peasantry ; he thus places the nobility as the eater among the peasantry. He lays down (some of) them in all the layers : he thus places the nobility as the eater among the whole people.

Again :[97]

And the seasonal (bricks), indeed, are also the nobility ; by the (different) layers he thus builds up the nobility above (the peasantry)...Let him not thereafter place over them any other brick with a sacrificial formula, lest he should place the peasantry above the nobility.

And so on. Many more passagees like these can be quoted from the *Satapatha Brahmana.* But that is not necessary. What is necessary is to note that the ritual placing of the bricks in the text is designed also to serve a frankly political purpose. For the brick technology itself the priests could have depended on the Harappan survivors, because we have so far no knowledge of any other tradition of highly sophisticated brick technology ante-dating or contemporaneous with the *Satapatha Brahmana.* What seems to be distinctive of the text, however, is the addition to it, and that includes this political philosophy, because the text—like the literature of the Vedic priests in general—belongs to the period of the rising

95. *Sat. Br.* vi 4.4.13 Tr. Eggeling.
96. *Ibid* viii. 7.1.2. Tr. Eggeling.
97. *Ibid* viii. 7.1.12. Tr. Eggeling.

political power of the nobility on the ruins of the ancient tribal organizations of the early Vedic peoples. In such a period, the strengthening of the political power of the nobility —though by magical rituals—was only likely to be a paying proposition for the priests.

Eggeling in his own way notes this political motivation in what he calls the "sacrificial metaphysics" of the *Satapatha Brahmana*, or, more specifically, in those portions of the text discussing the question of the altar-construction. We may profitably quote him at some length :[98]

The theologians of the Brahmanas go, however, an important step further by identifying the performer, or patron, of the sacrifice—the Sacrificer—with Prajapati ; and it is this identification which may perhaps furnish us with a clue to the reason why the authors of the Brahmanas came to fix upon 'Prajapati' as the name of the supreme spirit. The name 'Lord of Creatures' is, no doubt, in itself a perfectly appropriate one for the author of all creation and generation ; but seeing that the peculiar doctrine of the Purusa-sukta imparted such a decisive direction to subsequent dogmatic speculation, it might seem rather strange that the name there chosen to designate the supreme being should have been discarded, only to be employed occassionally, and then mostly with a somewhat different application. On the other hand, the term 'Prajapati' was manifestly a singularly convenient one for the identification of the Sacrificer with the supreme 'Lord of Creatures' ; for, doubtless, men who could afford to have great and costly sacrifices, such as those of the Srauta ceremonial, performed for them—if they were not themselves Brahmins, in which case the term might not be inappropriate either—would almost invariably be 'Lords of Creatures', i.e. rulers of men and possessors of cattle, whether they were mightly kings, or petty rulers or landed proprietors, or chiefs of clans. It may be remarked, in this respect, that there is in the language of the *Brahmanas* a constant play on the word 'praja' (progenies), which in one place means 'creature' in general, whilst in another it has the sense of 'people, subjects,' and in yet another the even more restricted one of 'offspring or family'.

Such, then, is the political philosophy of the *Satapatha Brahmana*. It is the political philosophy of a split society in which the powers and privileges belong to the "nobles" or "kings", though secondarily also to their ideological apologists, the priests, who take upon themselves the task of

98. Eggeling in SBE Vol. XLIII, intro. xv-xvi.

stabilizing with their magical rituals the power of the nobility, or, as Renou observes, "Vedism was in charge of a priestly elite who served a military aristocracy".[99] The details of such rituals often appear to us to be rather trivial, often making the texts almost unreadable even in standard translation. But that is not the impression the priests intend to give to their patrons. For the purpose of impressing the nobility of the efficacy of these trivialities, the essential points of this political philosophy is sometimes projected back on the ancient Vedic mythology which, as we shall later see, usually gives us the impression of a different political temper altogether—the political temper characteristic of the tribal collectives. For the priests of the *Brahmana*-literature, however, that does not matter. They freely tamper with what they themselves claim to inherit. Thus they project back their political views on the ancient Vedic pantheon itself and want their patrons to see in it the fulfilment of their desired reality. Class difference among the mortals is introduced among the ancient deities. The group of Vedic gods called the Maruts, for example, are now made to stand for the common people, while the despotic power of the nobility is represented by gods like Indra and Varuna. Here are typical passages illustrating this :

> Varuna, doubtless, is the nobility, and the Maruts are the people. He (the priest) thus makes the nobility superior to the people. And hence people here serve the Ksatriya, placed above them.[100]

> He muttered that verse addressed to Indra and referring to the Maruts. Indra indeed is the nobility, and the Maruts are the people... 'They shall be controlled', he thought, and therefore that verse is addressed to Indra.[101]

> Now some, on noticing any straw or piece of wood among the Soma-plants, throw it away. But let him not do this ; for the Soma being the nobility and the other plants the common people, and the people being the nobleman's food—it would be just as if one were to take hold of and pull out some food he has put in his mouth and throw it away.[102]

99. L. Renou, RAI 60.
100. *Sat. Br.* ii. 5.2.6.
101. *Ibid* ii. 5.2.27
102. *Ibid* iii. 3.2.8.

Some ritual details are sought to yield the symbolic interpretation of what "make the Ksatra superior to the people. Hence the people here serve, from a lower position, the Ksatriya seated above them."[103] Similarly, other ritual details are interpreted to show how "the Ksatriya, whenever he likes, says, 'Hallo Vaisya, just bring to me what thou hast stored away.' Thus he both subdues him and obtains possession of anything he wishes by dint of this very energy."[104]

20. GENERAL THEORETICAL TEMPER

With this political philosophy in mind—which, incidentally is characteristic of the *Brahmana*-literature in general—let us turn to the question of the general theoretical temper of the priests. For our present purpose, it is not necessary to attempt any exhaustive survey of the question. Our purpose here is only to ascertain how far is it credible to accept the Vedic priests as the makers of mathematics embodied in the Sulva texts. For this purpose it is necessary to take note of their theoretical temper, because the most outstanding characteristic of the Sulva texts is the insistance on accuracy of observation and this as usually having moorings on manual operation. If we ignore or overlook this characteristic, little or nothing of genuine mathematical interest is left for us in the *Sulva-sutra*-s. Hence it is impossible to evade the question : How much of of the zeal for accuracy of observation can be imputed to the Vedic priests, so that they can be credited with the making of this mathematics ?

From what is already noted about the political philosophy sought to be validated in the *Satapatha Brahmana,* it should be obvious that direct observation—and specially the accuracy thereof—cannot be a strong point of Vedic priests, notwithstanding their insistance on the meticulous observance of ritual details. In fact, all this ritual details have one purpose and that is the creation of awe and wonder, which, as Eggeling rightly observes, had always been the technique for promoting hierarchical aspirations. As he comments, "even practical Romee" could not do without it : "The Roman statesmen sub-

103. *Ibid* i. 3.4.15.
104. *Ibid* i. 3.2.15.

mitted to these transparent tricks rather from considerations of political expediency than from religious scruples; and the Greek Polybius might well say that 'the strange and ponderous ceremonial of Roman religion was invented solely on account of the multitude which, as reason had no power over it, required to be ruled by signs and wonders."[105] The same is perhaps all the more true of the Vedic priests who seem to have the additional anxiety of impressing the rich patrons financing for expensive sacrifices that these assured for them all sorts of material prosperity, besides absolute political power of keeping the direct producers—primarily the peasants—complete control.

The key, therefore, to the general theoretical temper of the Vedic priests is the technique of creating awe and wonder, of marvel and mystery, supported at best by weierd analogy and palpably absurd symbolism. What goes completely against all this is the description of things as they are, which, in its turn, evidently enough, results from direct observation. From the priestly point of view, therefore, direct observation specially with an interest in precision is on the whole undesirable. What is desirable instead is a mystical veil on things, under the cover of which they can best operate as effective ideologues.

Interestingly enough, the priests whom we meet in the *Brahmana*-literature are aware of this and they repeatedly express it, though in their own way. One of their favourite formulas is: "the gods love the mystic"—*paroksa-priyah iva hi devah* or *paroksa-kamah iva hi devah*. It is true that in the *Brahmana*-literature this dictum occurs mainly in justification of all sorts of fanciful etymologies concocted by the priestly corporations. But we shall see that in the *Brhadaranyaka Upanisad* —which, according to the Vedic tradion, is directly appended to the *Satapatha Brahmana*—Yajnavalkya himself wants to he very clear and categorical about its generalised philosophical implications.

But let us first have some idea of how—and how frequently —this dictum proclaiming the divine love or divine sanction for purposive mystification occurs in the *Brahmana*-s. We quote here some of the passages from the *Satapatha Brahmana* and this in the course of the discussion of the altar-construction :

105. Eggeling SBE XII. Intro p. x.

Now the embryo which was inside was created as the foremost (*agri*) : inasmuch as it was created foremost (*agram*) of this All, therefore (it is called) Agri : Agri, indeed, is he whom they mystically call Agni ; for the gods love the mystic. And the tear (*asru*, n.) which had formed itself become the *'asru'* (m.) : *'asru'* indeed is what they mystically call *'asva'* (horse), for the gods love the mystic.[106]

This same vital air in the midst doubtless is Indra. He, by his power (*indriya*), kindled those (other) vital airs from the midst ; and inasmuch as he kindled (*indh*), he is the kindler (*indha*) : the kindler indeed—him they call 'Indra' mystically (esoterically), for the gods love the mystic.[107]

And as to why it is called 'Ukha' ;—by means of this sacred performance and this process the gods at that time dug out these worlds ; and inasmuch as they so dug out (*ut-khan*), it (the pan representing the worlds) is called *utkha,'—'utkha* being what they mysteriously (esoterically) call *'ukha'*, for the gods love the mysterious.[108]

And, again, why he puts it on the lotus-leaf. When Indra had smitten Vrtra, he, thinking that he had not laid him low, entered the waters. He said to them, 'I am afraid : make ye a stronghold for me' ! Now essence of the waters there was that they gathered upwards (on the surface), and made it a stronghold for him ; and because they made (*kar*) a stronghold (*pur*) for him, therefore it is *'puskara' ; 'puskara'* being what is mystically called *'puskara'* (lotus-leaf), for the gods love the mystic.[109]

He said, Verily this one has lifted me from out of all evil ; and because he said 'he has lifted me ont (*udabharshit*)', hence (the name) *'udumbhara' ;—'udumbhara'* doubtless being what is mystically called Udumbara, for the gods love the mystic. 'Wide space (*uru*) shall it make (*karat*) for me'! he said, hence *'urukara' ; 'urukara'* doubtless being what is mystically called *'ulukhala'* (the mortar) ; for the gods love the mystic.[110]

Like practically all arguments in the *Brahmana*-literature the etymologies suggested are weird and absurd and, in any case, the text itself does not want us to take these seriously from the

106. *Sat. Br.* vi. i.i. 11.
107. *Ibid* vi. i.i. 2.
108. *Ibid* vi. 7.1.23.
109. *Ibid* vii. 4.1.13.
110. *Ibid* vii. 5.1.22.

philological standpoint, because all these are intended only to cater to the divine taste for deliberate mystification after all. At the same time, it will be an error for the historian of science today to ignore or overlook the possible consequences of the dictum for the development of science and scientific temper among the priestly corporations. Among the Vedic scholars there is a tendency no doubt to read in the dictum some spiritual significance eluding a superficial understanding of it. But the great idealist philosopher of the *Brhadaranyaka Upanisad,* Yajnavalkya, wants in his own way to put a stop to such speculations. Evidently he feels that the dictum is in need of some explication. While, therefore, delivering a grand metaphysical discourse to Janaka, the king of Videha, he comes out with it and declares :

paroksa-priyah iva hi devah, pratyaksa-dvisah[111]—"the gods are fond of the mystic (or mysterious or obscure) ; *they detest direct knowledge.*"

The brief expression *pratyaksa-dvisah*—conveying the divine distaste for direct perception—can have no purpose here but to bring out the full philosophical implication of the brief priestly dictum. And this seems to speak volumes. If the gods themselves detest direct knowledge or perceptual knowledge, the mortals can develop any craze for meticulous observation only by flouting the divine.

It may be objected that even in the *Brhadaranyaka Upanisad,* the philosopher Yaynavalkya wants to retain the implication of the priestly dictum restricted to the etymological questions.[112]

But are we really justified in taking Yajnavalkya's reiteration of the priestly dictum with the explicatory addition *pratyaksa-dvisah* as intended to be restricted to mystical etymology, i.e. of rejecting the possibility of it being a pointer to the general theoretical climate of the priestly corporations and their philosopher-successors ? The answer seems to be clearly in the negative. The entire structure of the grand world-denying metaphysics propounded by Yajnavalkya is, in an important sense,

111. *Br. Up.* iv. 2.2.

112. Samkara's commentary on the passage may give us such an impression.

based on the dictum of detesting direct perception, which, if allowed any validity, runs the risk of taking the material things of the world on their face-value or as real materials things. Here is only one example of how his philosophy depends on the censorship of direct knowledge. In the *Brhadaranyaka Upanisad* Yajnavalkya declares :[113]

> Verily, where there seems to be another, there the one might see the other ; the one might smell the other ; the one might taste the other ; the one might speak to the other ; the one might hear the other ; the one might think of the other ; the one might touch the other ; the one might know the other. An ocean, a seer alone without duality becomes he whose world is Brahman... This is a man's highest path. This is his highest achievement. This is his highest world. This is his highest bliss. On a part of just this bliss other creatures have their living.

We shall later have the occasion to discuss this philosophy in some detail. But we have already seen that *acarya* Prafulla Chandra Ray as a working scientist could see that the power and popularity of this philosophy had been an important factor accounting for the decline of the scientific spirit in India. For the present, let us return to the point we have been trying to drive at.

We have now some idea of the general theoretical temper of the Vedic priests not only from the political philosophy which they want mystically to validate but also from their oft-repeated dictum of the divine fondness for the mystic or the deliberately obscure and, therefore, by implication their distaste for direct observation. Before hastily assuming that these same priests were the actual makers of mathematics embodied in the Sulva texts, we cannot thus evade the obvious question : How far such a general theoretical temper can at all be conducive to the making of this mathematics ?

There seems to be only one answer to this question. And that is in the negative. All that was really life-giving to the Sulva mathematics must have been accuracy of observation and this as frankly connected with manual operation. Therefore, notwithstanding the fact that the *Sulva-sutra*-s come down to us as appended to the priestly manuals, there are considerations that make us very strongly hesitate to follow the gene-

113. *Br. Up.*, iv. 3.31-32.

rally accepted view that the Vedic priests were themselves the makers of this mathematics. The most overriding consideration for this hesitation is of course the fact that this mathematics presupposes a highly sophisticated brick technology, which, archaeologically speaking, is just inconceivable among the Vedic priests. To this is to be added the evidence of the general theoretical temper of these priests, which is incompatible with that which imparts real significance to this mathematics.

21. UNSOLVED PROBLEMS AND POINTERS TO FURTHER RESEARCH

Yet the mathematics in the Sulva texts is a fact, and, as a fact requires some explanation from the historian of science. We have failed, because of reasons explained, to subscribe to the facile view that it was created by the Vedic priests to meet the requirements of their sacrificial ritual. Hence we are required to look for some alternative explanation for its origin. At the present stage of research, however, such an attempt leads us at best to the realm of conjectures. This, in other words, means that the problem is in need of further investigation and research, and the conjecture we shall venture would be ventured only with the hope of drawing the attention of the more competent historians of science to its general plausibility, At the same time, we shall be obliged to mention the number of yet unsolved problems that such a conjecture ushers in.

The conjecture we are drawn to by the data available so far is as follows. Though codified at a much later period, the mathematics in the Sulva texts came down from a very ancient period and one is tempted to presume that it could be the period of the First Urbanization. The strongest point in favour of such a presumption is the imposing brick technology of the Harappan Culture, i.e. what still survives of it in spite of the well-known accounts of brick-robbery in a big scale. The mathematics in the Sulva texts, as we have repeatedly asserted, is inconceivable without the tradition of highly sophisticated brick technology which, from the archaeologists' viewpoint, is absent throughout the period of the *Yajurveda, Satapatha Brahmana* and the *Kalpa-sutra-s.* Even admitting a very late date of the codification of the *Sulva-sutra*-s (which are appended to the *Kalpa-sutra*-s), it is hard to believe that this could happen much later than *c.* 300 B.C., i.e. what the

archaeologists call the second phase of the NBP period when brick technology is reintroduced in some scale in Indian history. But the sophistication of brick-technology, the development of geametrical propositions wanted to meet its theoretical needs, the evolution of a whole host of terminologies to meet the requirements of this mathematics—all these and many other characteristics of the Sulva mathematics which still amaze us—evidently presuppose a very long time of development. That could perhaps be a number of centuries, though how many centuries remains anybody's guess. But it seems impossible to bring down the date of the Sulva texts many centuries later than the 300 B.C. Therefore, the only tradition of sophisticated brick-technology ante-dating the Sulva texts, as far as our knowledge goes today, is that of the Harappan culture. Since the Sulva mathematics is inconceivable without the tradition of a sophisticated brick-technology, it is difficult to reject outright the presumption that it developed during the period of First Urbanization though, as *somehow* transmitted to a much later period, it was codified in the form of the *Sulva-sutra*-s. We have emphasised the word *somehow,* because at the present stage of our research we have no knowledge of *how* exactly this could be transmitted. From the standpoint of our presumption, this therefore is a matter of further research and investigation.

In this connection, two points may not be irrelevant. We have in the *Satapatha Brahmana* and also elsewhere in the Vedic literature a list of the succession of teachers (*vamsa*-s). Max Muller[114] and other specialists in Vedic literature are, generally speaking, not inclined to look at the list as purely fictitious. The list is a long one and it wants us to take back to a very ancient period or a remote antiquity. Modern Vedic scholarship is yet to be clear about the exact implication of the list of succession of teachers. Here, therefore, is a point that may be further investigated from the viewpoint of our presumption.

Secondly, there seems to be a growing interest among our archaeologists to explore and excavate the sites of post-Harappan culture and they are giving us more information about

114. Max Muller HSL. 438 *Seq. cf.* also Eggeling SBE, XII, intro. pp. xxxiii f.

what is called the overlap of late Harappan Culture with cultures succeeding it. What is so far achieved by our archaeologists in this direction may not be very imposing. But the direction itself appears to be promising and it discourages the tendency to think that round about 1750 B.C. the Harappan Culture came to a complete extinction, leaving later Indian culture to inherit nothing from it.

It seems unfortunate that A. Ghosee, one of our ablest archaeologists, in the last chapter of his otherwise brilliant book *The City in Early Historial India,* appears to give us such an impression. Criticising specially the view expressed by S. R. Rao in *Excavation at Rangpur and other explorations in Gujarat* (*Ancient India,* 18 & 19, 1963 pp. 4-207), Ghosh[115] observes :

> It is now certain that there was a wide gap of seven to nine hundred years between the disappearance of these chalcolithic cultures and the emergence of the historical period in the regions of their occurrence, so that the chances of the former having anything to do with the letter are extremely remote. And even more remote, actually non-existent, is the likelihood of any Harappan urban tradition filtering through them into northern India, where the historical cities sprang up not earlier than 600 B.C.

Again[116] :

> Archaeologists and anthropologists must recognize the phenomenon of the loss of ancient cultures. For example, what does survive of the Sumerian civilization in present-day Iraq, or of the dynastic civilization of the Nile in modern Egypt, or of the Sabaean-Himyaritic civilization in the contemporary life of south-Arabian peninsula ? In every civilization there is a point from which cultural traits can be traced onwards down to contemporary times, and so far as the Indian civilization is concerned, the Indus civilization is not that point.

Hence is his conclusion : "In building their cities in the early historical period the people were writing on a clean slate, with no Harappan nor any other mark on it."[117]

All this if intended to mean that the Harappan Culture came to an absolute dead end—or to something like an absolute zero

115. A. Ghosh, CEHI 77.
116. *Ibid* 85.
117. *Ibid* 89.

—with the final decline or destruction of its imposing cities, would hardly be accepted by most of the serious archaeologists. On the contrary, beginning from the days of R. P. Chanda and John Marshall, we have very significant light being thrown on later Indian religion by the material relics unearthed at the Indus sites, and, as for ancient Egypt and Mesopotamia we have before us the writings of Gordon Childe showing how the scientific achievements of these two other primary centres of "the urban revolution" are inherited and absorbed by later European culture. There seems to be no *prima facie* ground to argue that the third primary centre of "the urban revolution" was bound to be an exception to this. What is true, of course, about the observations of Ghosh just quoted is that there is a gap *in our knowledge* about the content and mode of survial of the Harappan achievements in later Indian culture; but this present *ignorance* is only *our ignorance* and to draw any positive conclusion from it about what objectively happened in Indian history would be no more logical than to argue that our failure so far to decipher the Indus script indicates that the Indus peoples themselves were pre-literate. Incidentally, it must be mentioned here that A. Ghosh himself, in some of his other writings—specially in his editorials in *Ancient India*, Nos. 10 and 11—does not give the impression of totally negating the Harappan "survivals" in later Indian culture.

We have argued all these in order to emphasise only one point. In default of any better hypothesis of the making of mathematics in ancient India, the presumption based on certain circumstantial evidences that it might have taken place in the ancient Harappan period cannot be summarily rejected, though how it came down to the later Vedic priests and could be adopted by them to add a new awe-inspiring dimension to their sacrificial ritual remains a matter of further research.

Such a presumption evidently takes it for granted that mathematics—and, for that matter, quite a sophisticated form of it —did develop in the Harappan culture. This, we are going to argue in the next chapter, is not an undue assumption. We propose to wind up the present discussion only with one point.

22. FUTURE OF SULVA MATHEMATICS

The mathematics of the Sulva texts, it is only reasonable to think, could not have come into being abruptly. The presump-

tion, on the contrary, is that it must have taken a long time—how long we do not know—to reach the stage of development it did. This, in other words, means that we have to infer some process of growth or development in the making of mathemetics in ancient India—a growth in which the theoreticians had largely to draw on the active experience of the technicians—specially of the brick-makers, brick-layers, architects and engineers.

What is apparently strange, however, is that historically speaking this mathematics came to an abrupt end. The mathematics of the *Sulva-sutra*-s—particularly the geometrical aspect of it—had really no future. Instead of developing, it simply withered away, leaving practically no legacy for later mathematical acivities in India, except perhaps, as Thibaut shows,[118] in the survival of some stray Sulva terminology—like *varga* and *karani*—though with new arithmetical-algebrical significance infused into them and this by pushing out the original geometrical interest of the Sulva texts. In any case, the positively geometrical interest of the Sulva mathematics lacks continuity of further development. As Thibaut puts it, "Clumsy and ungainly as these old *sutra*-s undoubtedly are, they have at least the advantage of dealing with geometrical operations in really geometrical terms, and are in this point superior to the treatment of geometrical questions which we find in the *Lilavati* and similar works."[119]

It is generally assumed that in the history of mathematical activity in India, after the Sulva texts the next mathematical work found so far is the *Bakshali Manuscript*—so called because it was discovered in a village called Bakshali (near Peshwar). Hoernle, to whose pain-staking work for years we owe a systematic restoration of the text, wants to put it in the third or fourth century A.D.—a date on the whole endorsed by serious schools like Buhler, Datta and others. Admitting this we are to place it in the advanced stage of Second Urbanization, with a gap of many centuries from the Sulva texts. In any case there is absolutely nothing to show any vestige of Sulva mathemetics in this work. Found near the crossing of many important trade-routes of the time, the contents of this

118. Thibaut in SHSI II. 476 ff.
119. *Ibid* 472.

work take interest in mathematics mainly in the sense in which the commercial communities care for their calculations. But more of this work later.

The real landmark of mathematical work in Indian history after this is the *Aryabhatiya*—the work of Aryabhata I who was born in A.D. 476. Though really a work on astronomy, it takes keen and skilled interest in mathematics, specially in its second part called *Ganitapada*. The reason for its interest in mathematics is quite obvious. Precise astronomical calculations are impossible without precise mathematical knowledge. In Aryabhata's work, we indeed come across a renewed interest in geometry. But this is geometry not in the sense in which we have it in the Sulva texts, for the simple reason that in the *Aryabhatiya* geometry moves away from the earth to the sky, i.e. is concerned with the positions, movements, etc. of the heavenly bodies. In short, Aryabhata shows hardly any legacy of the Sulva geometry presumably because by his time it had already become a dead curiosity of the past.

There were, of course, a considerable number of commentators on the Sulva texts. However, strangely enough, as Thibaut shows, they often misunderstand or misinterpret the mathematics of the Sulva texts. "Trustworthy guides as they are in the greater number of cases, their tendency of sacrificing geometrical construction to numerical calculations, their excessive fondness as it might be styled of doing sums renders them sometimes entirely misleading."[120] The most important reason for this, as Thibaut wants us to understand it, is that "they represent the later development of Indian mathematics."[121]

This last point is very clearly illustrateed by B. B. Datta. Rama, a commentator on *Katyayana Sulva-sutra,* quotes from the work of the later mathematician Sridhara (c. A.D. 750);[122] Sivadasa, a commentator on *Manava Sulva-sutra* quoted the second Bhaskara (*c.* A.D. 1150) ;[123] Karavindasvami, a commentator on *Apastamba Sulva-sutra,* quoted certain passages

120. *Ibid* 473-74.
121. *Ibid* 473.
122. B. B. Datta, SS, 11.
123. *Ibid* 12.

from *Aryabhatiya* ;[124] so did Dvarikanatha in his commentary on the *Baudhayana Sulva-sutra*.[125]

What else could the commentators do than go in for later predominantly algebric methods of demonstration when the genuinely geometrical promise of the Sulva texts came to some kind of dead end or, at any rate, failed to develop furher ?

Here, then, we have another problem which the historian of science in India cannot afford to ignore or overlook. Why was it that the Sulva geometry failed to have any further development ?

From the viewpoint of our own presumption the answer to this is not so difficult. From the circumstannce of this mathematics being inextricably related to brick technology—and failing to find any tradition of sophisticated brick technology antedating the Sulva texts except in Harappan Culure—we have presumed that this mathematics could have developed in Harappan Culture, notwithstanding there being various unsolved problems at the present stage of our research specially about its transmission to the later period. We have further presumed that in this later period, the Vedic priests wanted somehow to utilize this brick-technology perhaps from the stragglers of Harappan technicians, employing them for the purpose of building awe-inspiring sacrifical altars ; along with this brick-technology the mathematics—which was the outcome of the theoretical requirement of the technology—could have come down to the Vedic priests which they codified in the *Sulva-sutra*-s.

One advantage of this presumption, however, seems to be that it may throw some light on the apparent peculiarity of this mathematics having once a period of growth or creative development and yet having practically no future in the subsequent history of mathematical activities in India. This follows from the socio-economic function of the brick technology in the Harappan period and this as contrasted with the later Vedic period.

In the ancient Harappan period, the technology of making and using burnt bricks did have a very positive socio-economic function. Apart from being essential for defence against floods

124. *Ibid* 16.
125. *Ibid* 18.

—to which, as we have already seen the Allchins have very legitimately drawn our attention—practically everything that appears to be so spectacular about the Harappan Culture largely depended on brick technology : the houses, the citadels, the granaries, the drain-system, the dock-yards are just a few examples that should substantiate our point. The socio-economic function of brick technology in Harappan Culture is in fact so obvious that it requires not much elaboration. When a technology serves such a positive socio-economic function the theoretical requirements of it—in the present case, the mathematical knowledge required by it—acquires nourishment for creative development.

But what is the function of the same technology—or its survivals—as shifted to the later Vedic period? Its socio-economic function is not only just nil but definitely negative—because it is now harnessed to total economic waste—the building of some complicated structures for assuring the patrons financing the sacrifice that these would magically ensure for them the fulfilment of their desires like gaining cattle and food, annihilation of foes and quick transit to heaven. Beyond creating such apparently absurd and false assurances for the *yajamana*-s —and, incidently, validating in the course of the performance of the rituals the despotic power of the "nobles" of the age —brick structures of the Vedic priests had no function at all, or the only other function that these had was ensuring for the parasitical priest class their livelihood in the from of *daksina*-s or sacrificial fees which, according to the Dharmasastra norm, was about the only legitimate source of income for them. Harnessed to such total economic drainage, neither the brick technology nor the theoretical outcome of it—namely geometry—could have any future. And the fact is that these had none in the Vedic tradition itself.

C. G. Kashikar argues, of course, that it is wrong to think that bricks were used during the comparatively later Vedic period exclusively for ritual purposes. "It cannot be said," he observes, "that the bricks which then presumably formed an essential material for house-building, were employed only for the ritual purpose."[126] But what is the basis of this as-

126. C. G. Kashikar, in *ABORI* 1981, 126

sumption that bricks were then used for house-building? Surely not any archaeological evidence, because the archaeologists have so far not been able to find any relic of brick-built house in the Vedic settlements proper usually assumed to be the PGW sites. In default of archaeological evidence, Kasikar has recourse only to literary evidence. But as we have already seen, the only literary evidence he manages to cite is as follows: "Bricks as house-building material are mentioned in Kesava's *Paddhati*."[127] Though claiming to belong to the Vedic tradition—for it is a commentary on a *Srauta-sutra*—the date of the *Paddhati*, according to Kashikar himself, is 13th century A.D. Quoting the evidence of such a late text in substantiation of what is alleged to be true in a period anterior to the fifth or sixth century B.C. seems hardly to be a way of writing history, specially when the thesis built on it flouts an overwhelming mass of anchaeological data.

127. *Ibid* 126 n.